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THE TENNESSEE VALLEY PROJECT: *A paper read at the Evening Meeting of the Society on 8 March 1937, by*

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IN many ways the Tennessee Valley project is the most remarkable of the schemes fostered by the United States Government to promote economic recovery. From the engineering point of view its structures are less spectacular than those of Boulder Dam or the Grand Coulee Project. At first it had less news value than the tide-harnessing power plant in Maine, the flood-control work on the Mississippi, or the hundred-million-dollar canal which is to irrigate Imperial Valley. Nor does it compete in local public interest with many schemes in which the Federal Government is cooperating with city or state authorities, such as the Golden Gate Bridge at San Francisco or the new tunnel under the Hudson River at New York. But as an attempt to attack on a wide front the major economic problems of a region it has no equal.

The Tennessee and its tributaries drain a basin of 40,600 square miles—four-fifths the area of England—covering two-thirds of the state of Tennessee and parts of Virginia, North Carolina, Georgia, Alabama, Mississippi, and Kentucky.

The river draws its water from a region of varied geological structure which gives rise to correspondingly marked contrasts in topography, soil conditions, and vegetations. The great Appalachian valley is flanked by two strips of higher land, the Cumberland plateau and the Blue Ridge (here broadened into the Great Smokey and the Unaka Mountains), extensions of structures which parallel the Atlantic coast for over 800 miles.[1] The sharply folded strata of the Great Valley itself show wide variation in their resistance to erosion, the harder formations standing up in strong relief as long level-topped ridges separated by valleys 1000 or more feet deep. These ridges however are commanded by the still higher ramparts on each side—the crests of the Great Smokeys rise well above 6000 feet—and from such vantage points the Great Valley is seen to be well named (Fig. 2).

[1] G. D. Hudson, "Three major physical divisions of the Upper Tennessee Basin," *Econ. Geog.*, vol. 13 (1937), p. 93.

In shape the Tennessee basin is like a butterfly with outstretched wings. The right, or east, wing lies over the Great Valley and extends to lateral divides on the flanking mountains. In consequence the drainage shows two distinct patterns. The strikingly parallel tributary system north-east of Knoxville indicates the strong control of the underlying folds; the dendritic or irregular pattern of the North Carolina headwaters reflects the more complex structures of the Older Appalachians. The constriction at Chattanooga, near the meeting point of three States in the centre of the basin, forms the body of the butterfly. Here the Tennessee leaves the axis of the Great Valley by a series of spectacular incised meanders and follows a parallel marginal fold for 50 miles into Alabama. It then strikes abruptly west over the simpler, warped structures of the left wing past Muscle Shoals to the boundary of Mississippi. Thence it turns north at right angles across Tennessee and Kentucky to join the Ohio at Paducah, the combined waters finally entering the Mississippi at Cairo.

The basin thus includes ground ranging from 325 to 6700 feet above sea-level, with a mean annual rainfall ranging from below 40 to over 80 inches, and with equally marked temperature contrasts. Originally the entire region was forested but large tracts of the bottomlands and lower slopes have long since been cleared for farmland. The higher ground is still timbered and there are important undeveloped mineral resources. But the population is largely agricultural, living standards have remained low, and the trend of the last few decades has been down rather than up. This tendency is explained partly by the fact that the southerners in general, and the negro in particular, are easy-going; partly by the serious impoverishment of the land, which has lost much of its top-soil by erosion; and partly by a variety of historical and economic causes which have conspired to keep the region in a backward condition. Stated briefly, the plan of the Tennessee Valley Authority (T.V.A.) is to regulate and utilize the water resources for power and for river navigation; to introduce cheap electricity on a regional scale for use in homes, farms, and factories; to develop the mineral resources of the area; to check erosion by soil-conservation measures; and to improve crop yields by artificial fertilization, thus leading to radical changes in variety, quality and yield of agricultural produce. The scheme clearly calls not only for an immense amount of closely coordinated engineering, but also for a state-wide educative policy by which the people may learn to make the best use of the benefits thus brought to their door.

The present plan is the outgrowth of a long series of efforts to improve conditions in the Tennessee Valley. A century ago Congress made an abortive attempt to render the river navigable. Other schemes followed, and since 1900 channel improvement has been carried out on various sections of its course. During the war the demand for explosives led to the erection of the Muscle Shoals power plant at Wilson Dam near Florence, Alabama. But the emergency had passed before the nitrate factory was ready for operation and the plant was left as a white elephant on the hands of the government. Offers were made for it by commercial interests, but these were rejected. When I first visited the Muscle Shoals power-house in 1933, seven of its eight 20,000-kilowatt turbines were standing idle. The single operating unit was generating

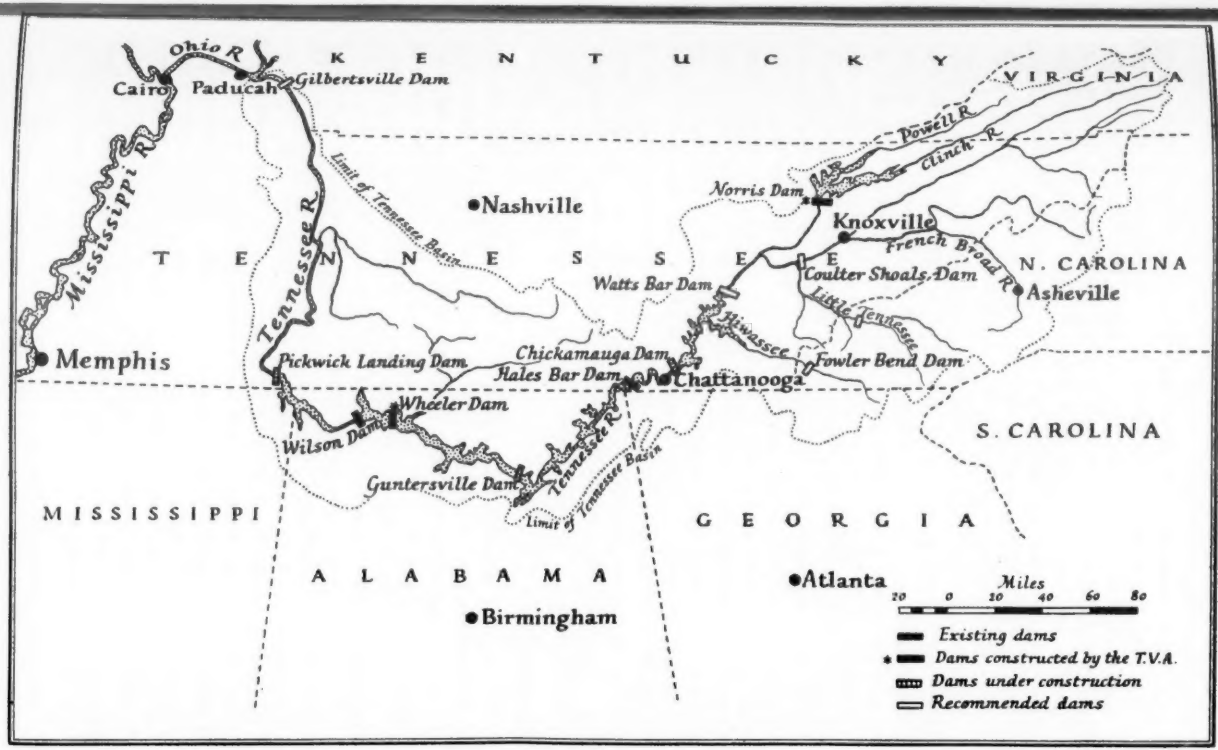

Ohio R
Cairo
Paduckah
Gilbertsville Dam
KENTUCKY
VIRGINIA
Mississippi R
Tennessee R
Limit of Tennessee Basin
Nashville
Powell R
Clinch R
Norris Dam
Knoxville
TENNESSEE
French Broad R
N. CAROLINA
Watts Bar Dam
Coulter Shoals Dam
Asheville
Little Tennessee
Hiwassee
Memphis
Pickwick Landing Dam
Chickamauga Dam
Hales Bar Dam
Chattanooga
Fowler Bend Dam
Wheeler Dam
Wilson Dam
S. CAROLINA
Guntersville Dam
Tennessee R
Limit of Tennessee Basin
MISSISSIPPI
GEORGIA
ALABAMA
Atlanta
Birmingham
Miles
20 0 20 40 60 80
Existing dams
Dams constructed by the T.V.A.
Dams under construction
Recommended dams

Fig. 1

enough electricity, under the care of a staff of five, to supply the electric needs of the largest city in the state.

The havoc wrought by the Mississippi floods had already drawn attention to the need for organized river-control. Under a previous administration Congress endorsed a comprehensive scheme for the study of all navigable rivers in the United States, from the viewpoint of (*a*) navigation, (*b*) flood-control, (*c*) irrigation, and (*d*) water-power. Boulder Dam,[1] on the Colorado River, was one of the projects which received impetus under this legislation. It was left for the Roosevelt administration to tackle the problem of the Tennessee basin as part of its relief works programme.

The charter governing the operations of the T.V.A. is careful to emphasize the navigation and flood-control aspects of its functions. Under the Constitution of the United States a sharp distinction is drawn between the fields of state and national legislation. In contrast to the localized character of the advantages gained from better irrigation and power systems, the benefits of improved trunk river communication and flood-control extend beyond the limits of any one state, and thus become questions in which Federal action or intervention can be legally justified. The N.R.A. (National Recovery Act) became a dead letter after it had been successfully challenged in the Supreme Court on the ground that Federal interference had exceeded constitutional limits by usurping functions reserved for state legislations. But while legal attempts on the part of utility interests to prove the T.V.A. unconstitutional oblige the latter to base its claim to existence on river regulation works, in practice and from the wider geographical standpoint this aspect seems less important than the anticipated by-products in schemes for economic rehabilitation.

Navigation

The problem of navigation is solved if a sufficient depth of water is present in the main channel at all times, irrespective of the volume of water flowing through at any given moment. Hitherto there have been reaches below Chattanooga with a low-water channel depth of 3 feet. At points farther up river it has fallen at times to 1 foot. Under the Act of 1933 with its later amendments,[2] the necessary channel improvement is to be achieved by erecting a series of dams which pond the water upstream to a minimum depth of 9 feet, combined with locks which will lift river boats over the barrages to the higher water above. As is seen from the map (Fig. 1) the Tennessee joins the Ohio River at Paducah, where its elevation is 325 feet above sea-level. At Knoxville, 650 miles upstream, the river is at 800 feet, implying an average fall of less than 9 inches per mile. However this gradient is not evenly distributed, a drop of 200 feet occurring in the 115 miles between Decatur and Savannah, with a maximum of 5 feet per mile at Florence near Muscle Shoals. It is therefore clear that the situation cannot be met by a series of pools formed behind equally-spaced dams of uniform height. Apart from this, the geological setting of the various sites involved such a diversity

[1] See *Geogr. J.* 86 (1935) 498.

[2] See Ann. Rep. Tenn. Valley Authority, 74th Congress, 2d. Session, House Document No. 536, Washington 1936, pp. 77ff.

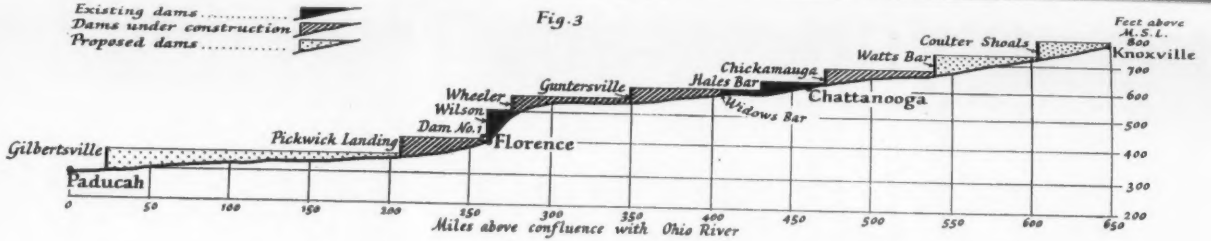

Existing dams
Dams under construction
Proposed dams
Feet above M.S.L.
800
700
600
500
400
300
200
Gilbertsville
Paducah
Pickwick Landing
Wilson Dam No. 1
Wheeler
Florence
Guntersville
Hales Bar
Chickamauga
Watts Bar
Coulter Shoals
Knoxville
Chattanooga
Widows Bar
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Miles above confluence with Ohio River

Fig. 3

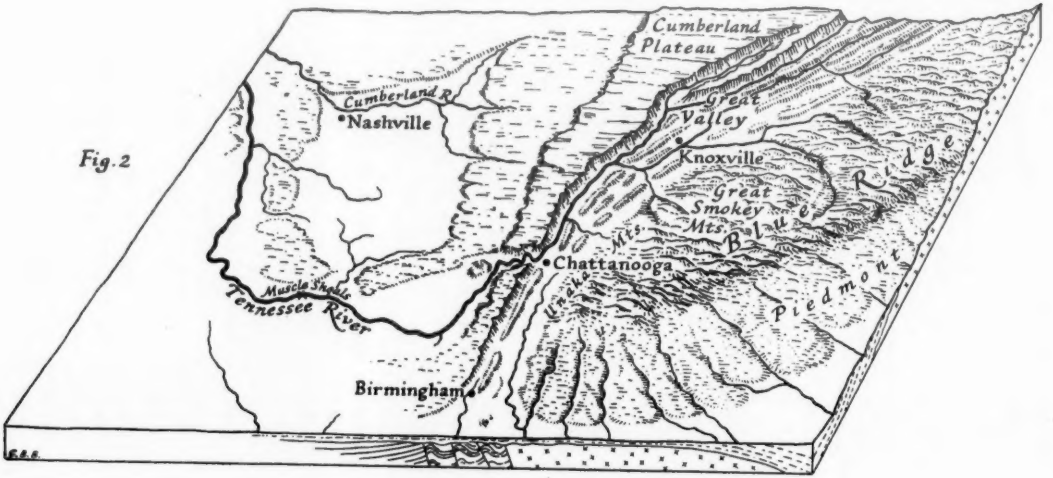

Cumberland Plateau
Cumberland R.
Nashville
Great Valley
Knoxville
Great Smokey Mts.
Blue Ridge
Chattanooga
Muscle Shoals
Tennessee River
Unaka Mts.
Piedmont
Birmingham

Fig. 2

of problems calling for special treatment that entirely different specifications are needed in each case.

As indicated in Fig. 3, dams were already in existence at Muscle Shoals (Wilson Dam) and Hales Bar, the latter being privately owned. The T.V.A. engineers have now completed Wheeler Dam, and work is well advanced on dams at Chickamauga near Chattanooga, at Pickwick Landing, and at Guntersville. Three more—Coulter Shoals, Watts Bar, and Gilbertsville at the confluence with the Ohio—will furnish a navigable waterway from Knoxville to the Gulf of Mexico. The main river dams in each case have the effect of deepening the water in the channel, so that there is a minimum of 9 feet at the foot of the next dam upstream. The length of the pool thus formed varies in each case with the gradient of the stretch involved: Gilbertsville (184 miles), Pickwick Landing (53), Wilson Dam (15), Wheeler Dam (74), Guntersville (81), Hales Bar (33), Chickamauga (59), Watts Bar (74), Coulter Shoals (44). It is estimated that by 1950 river traffic will have increased from below three, to over seventeen million tons per year with an annual freight saving of £4,700,000.

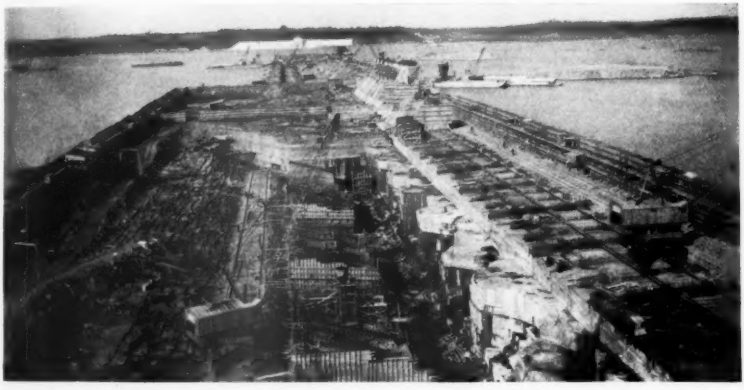
Flood-control

Besides the question of navigation, two other problems of water control call for attention under the unified scheme.[1] Seasonal fluctuations in discharge are important in any plan which must make provision also for flood-control and steady development of hydro-electric power. To meet this combined problem, three of the more important tributaries of the Tennessee —the Clinch, Hiwassee, and Little Tennessee rivers—are to be held in check by dams which will have no lock system. The reservoirs thus formed however will affect navigation in so far as they will regulate the river flow by holding back excessive discharges of rainfall and releasing them at a steady rate. This action will prevent flood water from overloading the Tennessee itself and will instead deliver a delayed supply to the main-river power plants, thus allowing these to work at capacity with a minimum of waste water passing over the spillways at flood crest.

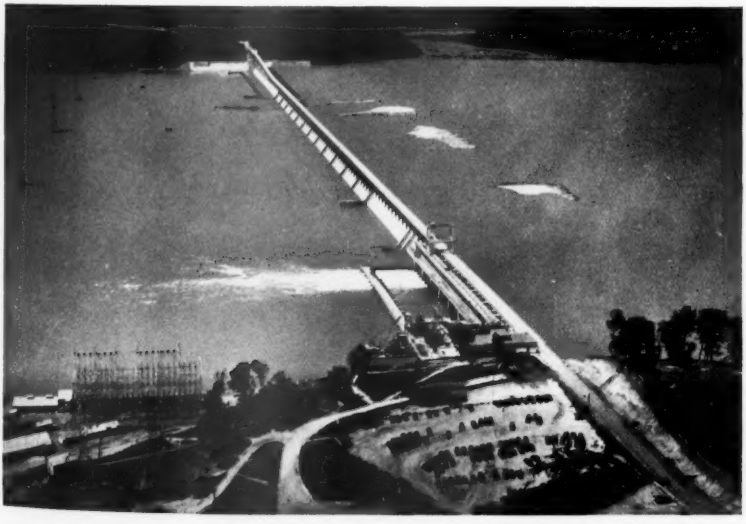
As the largest tributary of the Ohio, the Tennessee River is an important factor in the Mississippi floods. The mean annual rainfall in the Tennessee basin is 52 inches; a few head-water localities receive over 80 inches, while certain sheltered valleys have less than 40. At the peak of the great flood of April 1927, which inundated 28,000 square miles along the Mississippi, the Tennessee was responsible for 258,000 cubic feet per second or 14 per cent. of the total discharge, while at the earlier flood peak of the previous month it contributed 297,000 c.f.s. (20 per cent. of the total). Under the present plan, dams on the Tennessee and its tributaries will have a storage capacity of 7 million acre-feet, which may ultimately be raised to 10 million by further damming of minor tributaries. Of this total, $3\frac{1}{2}$ million acre-feet will be impounded by the main-river dams shown in Fig. 3. The value of these dams in flood-control will, of course, vary with the stage and duration of extreme discharge; but the retention of 1 million acre-feet during the 1927 flood would have lowered the peak stage on the Mississippi by 1·8 feet.

[1] Report to Congress on the Unified Development of the Tennessee River System, by the Board of Directors, T.V.A., March 1936.

First coffer-dam at Chickamauga



Construction of Wheeler Dam



Wheeler Dam completed

Mountain cabin in East Tennessee

Cinder block house built by the T.V.A.

The storage of water by dams placed in tributary valleys serves a double purpose. It is an essential part of the scheme of flood control and at the same time increases the available reserve of hydro-electric power. The Norris Dam on the Clinch River is the only one of these tributary-river dams actually completed. Each of its two turbines generates 66,000 horse-power. The difference in elevation between the minimum and maximum levels of the pool for generating purposes is 72 feet, giving a power-storage capacity of 1,710,000 acre-feet. For ordinary flood-control the water-level can be raised a further 27 feet above the spillway, thus storing an additional million acre-feet; in times of extreme flood a further raising of the overflow level by 5 feet will cope with another quarter-million. This of itself will reduce by over one-third the flood damage annually wrought by the Tennessee River above Wilson Dam. Norris Dam will pond back the water 72 miles up the Clinch River and 56 miles up its tributary the Powell, forming a lake 34,200 acres in area with a shore line of 775 miles. The projected reservoirs on the Hiwassee (Fowler Bend) and Little Tennessee (Fontana) will cover 6300 acres and 11,000 acres respectively. The T.V.A. has power to condemn and purchase the land that will be thus inundated, plus marginal strips liable to go under water at flood crest or needed for malaria control. This has necessitated the organization of a Resettlement Administration whose duty it is to arrange for the removal and housing of evicted families and to work out a far-reaching scheme for meeting their needs.

Dam construction

In building the dams considerable economies in engineering costs are being effected by a policy of serial construction. The dams are started in succession, technical staff and equipment being moved from site to site as the work at each progresses through various stages. When I last visited Norris Dam in June 1936, the electricians and turbine engineers were well installed in the quarters previously occupied by the cement gangs. The latter were setting up their gigantic concrete-mixers at Chickamauga, the next site, which in turn was being partially vacated by the excavation and blasting crews. Somewhere still further in advance core-drilling crews, geologists and engineers were at work securing the data needed for the blue prints of the next structure. The result is an increased efficiency as the work proceeds and a fairly uniform employment. The full advantages of this scheme of serial construction are only realized when the various phases of work are planned to advance at carefully geared speeds, which allow each stage to go smoothly ahead without holding up other work that must dovetail into the unified plan.

Norris Dam is over 1500 feet long and its tail extends apron-fashion to a point 204 feet downstream from the up-river face. In order to speed up the cement-casting after the foundations had been cleared, it was necessary to deliver semi-liquid concrete to different sections of the dam in turn, allowing each pouring to set before more was cast on top. To avoid having to resort to cooling by artificial refrigeration, individual pourings were limited to 5-feet depths and an interval of three days was allowed before the next pouring on the same block so that the heat generated by the setting

cement might dissipate naturally. Batches of concrete from giant mixers high on the valley walls had therefore to be deliverable without delay at any point over an area of 30,000 square feet and anywhere from zero to 265 feet above the bed rock. To achieve this, two cable railways were suspended between twin towers of steel framework on bogies which could travel laterally on parallel railway tracks on either side of the valley. The engineer in the control room on the north bank could move either pair of towers simultaneously up or downstream by an electric system of remote control, and thus bring the charge of concrete exactly over any desired spot without interfering with work in progress 30 feet away. The greatest amount poured at Norris Dam in any one 24-hour period was 4108 cubic yards. The concrete was cast in blocks 56 feet long which are keyed into each other, each block having embedded in it sensitive electrical and mechanical apparatus to detect and record the least changes of temperature or pressure due to yielding under unequal strains, to leakage among block-joints, or to alterative chemical changes in the composition of the material.

One of the hazards of using sites where reservoirs are made over eroded sedimentary strata of unequal resistance or faulted structure is the risk that the very weakness which originally determined the position of the valley may become a line of underground leakage after the water pressure on the bottom is raised by damming. At other points there is danger that the limestone bed rock has been honeycombed by solution cavities, often clay-filled, and will not prove water-tight. In the case of the Chickamauga Dam, $5\frac{1}{2}$ miles of core borings were drilled to explore the character of the foundations. In some instances vertical bore-holes 36 inches in diameter were driven in solid rock so that foundations or material to be used for concrete aggregate could be inspected *in situ* by men lowered into the hole. Where foundations were suspected of leakage, liquid cement was forced down drill-holes under high pressure until the resistance remained constant over a period of twenty-four hours, thus showing that water could no longer find a way of escape along any cavities which might have existed previously. As material for this grouting, use was made of a natural volcanic ash cement (metabentonite) of which there is a supply in the region, the local product proving specially suitable for the purpose; under test its tendency to "fluff," or become cellular on setting, is only a fraction of that of metabentonites from Mississippi and Wyoming.

The design of each dam is determined by its purpose and by the geological conditions of the site. Hence no two of the eleven projected dams are to be alike. The six already under construction will be completed by 1940 at an estimated inclusive cost of about £37,000,000, while the programme allows of the remainder being ready by the end of 1943 if sanction is obtained for the entire plan of development recommended by the engineers.

Hydro-electric power

The "unified plan" calls for a coordination of the stream-flow regulation needed for navigation and flood-control with the requirements for generation of electric power. Fortunately the conditions for meeting these needs are not mutually inconsistent; in fact both sets of requirements can be largely met simultaneously, for each is best served by a steady supply of water.

Thus if flood-water is held back in Norris and other tributary reservoirs while the main-river power plants at Wilson and Wheeler dams are running at capacity, and is released later during the period of low flow, not only are current conditions in the channel stabilized for navigation purposes, but spillway wastage is reduced and the prime power capacity of the whole generating system is increased. Using the hydro-electric equipment already installed at Wilson, Wheeler, and Norris dams, the continuous power development will amount to 205,000 kilowatts, while when the other projected generator plants are completed the total will reach 600,000 kilowatts, or one-third more than the output of the American plant at Niagara Falls. The entire system is united in a single grid, permitting the load to be transferred and distributed as conditions require. It would be out of place here to describe the technical aspects of the electrification scheme, but the view of Norris Dam gives an impression of a typical two-unit power house.

One of the aims of the electricity programme is to find out on a regional scale what electric power should cost the consumer and thus establish a "yardstick" for power, based on the assumption that cheaper electricity leads to greater consumption and hence lowers unit production costs. The T.V.A. does not attempt to deal with the consumer directly. Power is sold under contract to municipal and other distributing organizations at wholesale rates only just below those obtaining throughout the country; but the contracts also fix the retail charge at a very low rate.[1] Though this is often only half the rate previously charged by distributors, the loss is soon covered by increased use of electricity. Many of the smaller towns have doubled their consumption within two years. Though in general the privately owned utility corporations have been up in arms against what is regarded as government subsidized competition, an unexpected result of the policy has been that in some cases private companies have already found the value of the resulting lowered rates. One local power and light company which contracts with the T.V.A. for cheap electricity was able so to reduce its rates and increase its sale to home consumers that it actually led the country in its rate of growth for the year.

At present much of the power is turned directly back into the construction work. A 154,000-volt transmission line from Wilson Dam to Pickwick Landing supplies power for excavation, haulage, lighting, etc. at the new dam site. When construction has been completed, the policy laid down is that the needs of the farm and home are to be regarded as having the first claim. When these have been met, any balance of current not required for federal needs is available for industrial purposes at still lower rates.

Agricultural reconstruction

An even more radical change in the economic geography of the region is the rehabilitation of agriculture. The total area under T.V.A. supervision covers 40,600 square miles. Two-thirds of this land is owned by farmers, who constitute roughly one-half of the total population of two and a half million

[1] Contracts with one of the existing companies specify that the standard residential rates shall be 1½*d.* for the first 50 kilowatt-hours consumed, falling progressively to one-fifth of a penny when consumption exceeds 400 kwh.

of the valley, and half the surface of the basin is in constant use for crops or pasturage. Among the causes for the backwardness of the region have been the depletion of mineral content of the soil through failure to use any form of crop rotation or artificial fertilization, the progressive impoverishment of the ground by the removal of fertile top-soil from tilled land by rainwash, and the gullying of entire hillsides by run-off. The blame to be placed on the farmer for the worst of this soil-stripping cannot be questioned by any one who has followed the Clinch, the French Broad, or any other of the main tributaries towards their sources. Even where the gradient is considerable, these headwaters are clear streams, excellent for fishing, and only turbid after heavy rain. In the farm belt however the water is loaded with fine sediment and clarifies only when the silt has a chance to settle in one of the newly formed reservoirs.

On moderate slopes erosion is combated by using check-dams and brush mulch to hold the soil in place until a new protective cover of vegetation has gained a hold. Over seven million trees were planted in a year and a half in connection with such re-afforestation work and 86,000 check-dams were built during the same period. On gentler slopes, re-grading combined with grass planting is found sufficiently effective. With erosion proceeding at its former rate, the silt deposited along the shore-line of Norris reservoir would have filled it in a century. Under erosion-control, the life of the lake will be extended by 600 years.

Improvement of farmland itself is achieved by the use of artificial phosphate fertilizer produced at the Muscle Shoals plant at one-third the cost of standard commercial phosphate of identical potency.[1] During 1935 two thousand farms were used for demonstration and experiment purposes, the farmer concerned agreeing to carry out instructions and keep records of crop yields in return for free fertilizer and other assistance. With the cooperation of agricultural experiment stations a greatly increased range of crops is being introduced and tested under conditions adapted to local needs. It has now been established that by soil enrichment the yield hitherto considered normal for a given acreage can be secured from half that area. With the help of fertilizer the farmer could secure his present crop from half his land; he could thus let the other half go fallow, turn it back into pasturage, and both protect it from further erosion and increase his income by raising livestock.

In an instructive article,[2] Stuart Chase has summarized the results of a study made of the resources of the four thousand families moved from the site of Norris reservoir in preparation for the flooding of that part of the Clinch river valley. The average annual cash income was less than £20, which was expected to meet the simple needs of a family with a relatively high birth-rate (one-fifth higher than the average for the entire United States) and in many cases of negro race. The whole county in which Norris Dam is situated and from which Chase's data were taken was the subject of an economic balance sheet prepared by Arthur L. Pollard. The district is

[1] Commercial acid phosphate contains 16 to 20 per cent. plant food; T.V.A. triple superphosphate, 43 per cent.; T.V.A. new phosphatic fertilizer now being tested, 62 per cent.

[2] *The Nation*, New York, 3 June 1936, p. 702.

Heavily eroded slope in Norris Dam area

The same hill eighteen months later after treatment by the T.V.A.

Check dams and brush mulch being used to prevent further erosion

The same area now covered with black locust

entirely agricultural, so that everything imported must be paid for by native products, two-thirds of which are so utilized, the remaining third being consumed by the inhabitants. The balance sheet for 1932 reads:

Expenditure		*Income*	
To food and clothing ..	£59,000	By sale of crops	£85,000
„ motor car expenses ..	24,000	„ outside labour	4,000
„ education, farm machinery and miscellaneous	24,000	„ tourist income	4,000
„ taxes, depreciation, etc.	57,000	Total operating income ..	£93,000
Total expense ..	£164,000	County deficit	£71,000

This deficit is reduced by state aid for schools and roads, federal aid, and insurance receipts to the extent of £28,600, leaving a net deficit of £42,400 as the amount by which that county sank further into debt for the year. It is not hard to understand why a plan of development which promises to bring prosperity to the district has received such a welcome.

The by-products in the improved conditions in the area are already marked. Houses are being rebuilt to take advantage of water supply now made possible by electric power. Life on the farm has new amenities and sources of income, offering counter-attractions which may stem the drift of young people towards the towns.

Technical Staff

In a brief account it is impossible to do more than mention some of the side lines which have had to be developed in connection with the primary undertakings of the T.V.A. The last annual report to Congress, issued in 1936, gives the names and salaries of 4875 skilled employees (earning over £300 per annum) out of a total T.V.A. pay roll of over sixteen thousand. Merely reading over their official designations is instructive, revealing the unsuspected directions in which the ramifications of the work extend. In addition to the vast army of draughtsmen, surveyors, carpenters, riggers, concrete workers, electricians, steelworkers, mechanics, engineers, and office staff of all kinds, one finds such titles as timberman, junior forester, erosion engineer, supervisor of grave removals, associate title examiner, dormitory supervisor, junior sanitary inspector, mail sorter, cadastral engineer, acid plant supervisor, physical training and recreation (negro) supervisor, core-drill operator, fire-fighter, filter plant operator, high school English teacher, assistant town manager, multilith photographer, chemistry patent attorney, soil analyst, ceramic research assistant—each title at once suggesting a department of work that has its place in the scheme. One of the highest paid specialists is an expert dendrochronologist. While one may be in doubt as to the precise activities of individuals classed as marine pilot, assistant geographer, and river transmission foreman, the report is specific as to the functions of the air-pilots. The three aeroplanes of the T.V.A. are used for four purposes—aerial mapping (especially during times of flood), malaria control by dusting reservoir shore-lines with insecticide during mosquito breeding seasons,[1] emergency

[1] The alternative method is to lower reservoir levels and then raise them again to let fish have access to the pools of marginal standing water just before the larvae are due to hatch.

transportation, and forest-fire patrol. Seventy-five forest fires were reported by air-patrols during a single season, thirty of them in localities out of range of the forest-rangers' look-out towers. Besides investigating the soundness of dam-sites and drainage problems, the geologists have been busy making careful estimates of the mineral resources of the basin. In addition to the natural phosphates which furnish the raw material for the fertilizer plant, the district has considerable deposits of coal, copper, iron, and manganese awaiting development. Less important reserves of nickel, chromium, and petroleum are reported, and research laboratories are testing the value of raw materials for the cement, chemical, and ceramic industries.

The need for expert help in such a variety of departments has led to the thorough-going cooperation of a large number of government departments that has itself been a valuable lesson. Moreover the freedom of action given to the executives has enabled them to increase efficiency by insisting that all appointments shall be made strictly on the basis of merit alone.

Policy

The ultimate success of the scheme depends largely on marketability of the power not needed by the phosphate plant or other federal activities connected with the project. To ensure the absorption of this electricity by the public, a programme of rural electrification has been developed and encouragement is being given to industrial activity. For the agricultural districts a wide transmission network is being erected (with duplicate transmission lines to provide against interruption of service through breakdown due to storms or accidents), loans for easy purchase of labour-saving machinery are available for householders and farmers, and every imaginable electric device that appeals to the housewife—dish washers, carpet sweepers, cooking ranges, coffee percolators, and sewing machines—is displayed in the shop windows of the towns. A model settlement has been built at Norris, where the visitor may inspect attractive houses with electrical cooking and heating equipment, built to standard specification at surprisingly low costs.

The T.V.A. is ready to discuss with any community, or other organized group within the area, the methods best calculated to improve agricultural conditions in the locality in question. These methods may involve rotational use of soil-protecting or soil-improving crops, enrichment of soil by fertilizers, or reduction of areas of tilled or bare land. Typical farms are then selected for demonstration experiments, and fertilizer, crops, and equipment are supplied.

In order to secure the extension of power lines to any district, its farmers must first be organized as a cooperative group. Stuart Chase gives an amusing example of the technique used to overcome local prejudices in conservative communities whose first attitude has been somewhat non-cooperative. "The T.V.A. agents call a meeting and simply tell the story of what rural electrification means, what it costs, and what its benefits are. Then they pack their charts and prepare to leave, remarking, as they take their hats, that this particular county is a difficult one to service. The meeting, they point out, was only called to place the general news before the farmers. Some day perhaps if all goes well, a line might be arranged. But hardly now.

No, indeed, not now. . . . From defensive the audience turns to offensive. Why not now? What's the matter with our county? Why can't *we* have what other counties have? Mister, where are those blank forms? We'll have a full list of names for you to-morrow—no, to-night! And we'll sign up those 662 kilowatts per mile. What do you mean, we *can't* have T.V.A. power now? . . . And the cooperative is enthusiastically launched under its own steam, with full local responsibility!"

Cost

It will be many years before a balance sheet can be struck that will permit a final estimate of the precise financial and economic success of the project. The outlay on work already in progress and destined to be completed by 1940 is estimated at $185,188,525 (£37,000,000). This does not include the cost of Wilson Dam and other projects previously carried out at public expense by other agencies than the T.V.A., which total $49,400,000 (£10,000,000). For the full realization of the potential benefits of the unified plan, legislation is impending which will extend the construction work until 1943 at a further cost of $144,500,000 (£29,000,000). The grand total thus amounts to something in excess of £75,000,000, spread over a period of ten years and taking into account work previously done by independent agencies. But, viewed in comparison with other items on governmental budgets of the present decade, the figure of £7,000,000 sterling per year does not appear excessive for a project which promises so much.

Note.—The photographs illustrating this paper were courteously provided by the Tennessee Valley Authority.

DISCUSSION

Before the paper the CHAIRMAN (Colonel Sir CHARLES CLOSE) said: The President, Professor Balfour, unfortunately is not well enough to attend this evening, so he has asked me to take his place. The lecturer to-night is Mr. George Barbour, who has already lectured to us on the floods in China and in America. To-night he has an equally watery subject, so I understand, in the Tennessee Valley Project, a subject that we shall know all about in an hour's time. Mr. Barbour, in addition to being a very distinguished geographer and geologist, is a distinguished broadcaster. He has broadcast to secondary schools, and I dare say that those in this audience who are under sixteen will remember some of his broadcasts! I looked up his address in *Who's Who*, and I found that he had one address in Pekin, one in New York, and one in London, so I said to myself: "He is going one better than Sir Boyle Roche's bird," but I understand that he is now living in London. At any rate, he is here now, and we hope to listen to a very interesting lecture, which I will now ask Mr. Barbour to give to us.

Mr. Barbour then read the paper printed above, and a discussion followed.

The CHAIRMAN: Dr. Julian Huxley knows something about Tennessee, so I will ask him if he will kindly address us.

Dr. JULIAN S. HUXLEY: There is not really very much that I can say to dot the i's and cross the t's of this most interesting lecture. I think we might remember the interesting geographical fact which was shown on the map, if not actually mentioned by the lecturer, that the Tennessee River, in spite of its enormous

size, being over one mile wide at one of the big dams, is not a tributary but a secondary tributary; it is a tributary of the Ohio River, which is itself a tributary of the Mississippi. That fact, in conjunction with the fact that the area concerned is four-fifths the size of England, helps to bring home to us, better than anything else could do, the scale of American scenery and American operations.

A second point which the lecturer has stressed, but which I think might be stressed even more, is that this is the largest project of regional planning in existence. You may say that the U.S.S.R. is still larger, but that can hardly be called regional planning; it is continental planning. This is the only case that I know of a really large scheme of regional planning in a democratic country, and it illustrates extremely well what excellent results can be obtained with a modicum of control and compulsion. The project is worked through three outstanding men, one of whom, Dr. A. E. Morgan, especially deserves to be mentioned; a very remarkable man, as I think Mr. Barbour will agree, a man of vision and practical ability combined. Executive power is delegated to these three men, somewhat in the same way as we delegate power to our Electricity Commissioners. I think that is the method by which big regional planning schemes must be worked, *i.e.* by giving a great deal of power for a considerable period to a few carefully selected men, so that they can carry out their ideas free from political interference. Although, as the lecturer said, the control of navigation is the peg on which the whole project is hung, the scheme is a very broad one. In the Act which gave powers to the T.V.A., and incidentally provided $50,000,000 to start the scheme, the T.V.A. is enabled to conduct any experiments or demonstrations which might conduce to the general welfare of the area. That gives them very broad powers.

There was one geographical fact which impressed me very much on my visit to the T.V.A. area—a fact also of great practical import. I have lived and travelled a good deal in America, and I am used to turbid rivers. The Tennessee river, like so many rivers of the south, is a turbid, yellow river. I had accepted this yellow turbidity as a fact of nature, but, to my surprise, when I was being shown over the Wilson dam the engineer told me that there were people still living who remembered the Tennessee river as a clear, pellucid blue stream. This turbidity is a product of man's interference and is a measure of the erosion which is taking place. In Tennessee erosion is a terrible problem, and it has been aided and abetted by the extremely uneconomic methods of cultivation of the poor whites. I am not sure that I altogether agree with the lecturer that it is the negroes who make this area such a problem. I should have thought that the poor whites created quite half of the problem. They live very primitive lives; they do not practise birth-control but have large families; they are very conservative and do not like to move away; and they are very primitive in their methods of cultivation. In some places they have adopted the method of shifting cultivation, which I used to think was practised only by savage tribes. They cut down a piece of forest on a slope which is much too steep to be cultivated efficiently, and cultivate it very badly for a few years until all the top-soil goes; then they leave it and go on to another area. It is largely the cultivation of steep slopes that has led to the terrible erosion; some of the land might not be eroded if it was kept as grassland for pasture, while other parts should be re-afforested.

The lecturer referred to the nitrate factory at Muscle Shoals, but that is actually a thing of the past. A large nitrate factory was started there, but now that nitrates can be produced so cheaply, I think I am right in saying that no nitrate is produced there at all, the whole emphasis being laid on the production

of phosphate. This is on a gigantic scale. I must say that, with my recollection of the chemistry laboratory at school, I was rather impressed on being told that a certain pipe about 5 inches wide was for pumping liquid phosphorus!

Another point which may be of interest is the geographical research work and its practical application in the form of surveys which is taking place at the headquarters of the T.V.A. The most elaborate surveys are being made, and new methods of making regional surveys are being worked out there for various purposes.

The lecturer referred to the work of the dendrochronologist. A dendrochronologist is a man who investigates the climate of the past by measuring the rings of trees; he can tell how the climate changed by measuring the change in relative thickness of the rings. Most interesting results have been obtained by that method, especially in the Arizona desert, and the method is being adopted in the Tennessee Valley in order to ascertain the maximum of drought to be expected, so as to find out whether the dams will always supply enough water for the power required. The T.V.A. dendrochronologist found that existing trees carried them back about 350 years, and logs in cabins built by the early settlers another 150 years; and the Archaeological Section found stumps of trees in an old Indian temple which carried them back another 200 years beyond that.

Speaking from the political point of view, as far as I am aware this is the first large-scale government enterprise in America in connection with which there has been no nepotism or "spoils system" in the appointments, and I feel that here we have the beginning of a new spirit. The scheme is really a yardstick, to use the American expression, not merely for power production but also for the whole of the planning of an area, and I wish that some of the authorities in this country would see to it that we should initiate schemes of regional planning on the same proportionate scale as is being done in the Tennessee valley.

Mr. GEORGE BARBOUR: In reply to Dr. Huxley, I am sorry to say that he is wrong in his description of the dendrochronologist. The dendrochronologist was a woman!

The CHAIRMAN: I was glad to hear something about the climate and rainfall of Tennessee. I looked up the subject in the usual books of reference, and I found that Tennessee had the most perfect climate. It is on the same parallel of latitude as Gibraltar and Cyprus, and it is said to have one of the best climates in the world, but it has 40 inches of rainfall in the year, whereas in London we have only 22 inches.

With regard to Dr. Huxley's remarks about influence in high quarters, I read the other day in the March issue of the *Fortnightly Review* a little quotation from Will Rogers; he describes how when representatives go down to their constituencies they must always try to bring something; they must bring a new post office or a new road or a new railway, whether it is wanted or not; but, he says, "the height of statesmanship is to come with a dam"! I was very glad to hear Dr. Huxley say that there was no ulterior motive in this dam.

In this country we cannot deal with such enormous schemes. For one thing, we could not take in a river 650 miles long. But we are all very much interested in the way in which American engineers, from whom we have a great deal to learn, have tackled the problems involved. In them we find ingenuity at its very best; they are doing nothing but good to humanity, and we wish the project the greatest success. I do not think the Tennessee Valley project is the largest of such projects in America. There is the Columbia River project in the State of Washington, which is a good deal bigger, but at any rate the Tennessee Valley project is sufficiently large. Eventually it will provide 3,000,000 horse-

power; that is 3,000,000 times 550 ft. lbs. a second. You can calculate what that comes to!

The lecture to which we have listened with such interest this evening has dealt with an instance of human geography, and in this Society we must more and more tackle that side of geography. Human geography is going to be the most important aspect of geography in the future. The type of material which the lecturer has given us is really the main substance of geography nowadays, and, because he has given us such an admirable account of this very important undertaking in America, and because he has described it so well, and so racily, I am sure I am right in offering him your very hearty thanks, as well as those of the Society, for his lecture.

THE TRANSPORT OF SAND BY WIND

MAJOR R. A. BAGNOLD

1. *Introduction*

THE following is an account of my recent experimental work on the mechanism by which sand is moved by a wind over surfaces of sand and pebbles. The work has in the main been limited to flat, horizontal surfaces, but deductions are drawn concerning the growth and nourishment of dunes.[1]

The subject of course is but a special case of the general problem of the transport of solid particles by fluids. The Reynolds' Numbers involved are of the same order, whether sand is transported by air or water, and the type of motion of the grains, and their resulting drag on the fluid, appear to be much the same, though too close a parallel should not be drawn since the density ratios of sand and fluid differ greatly in the two cases. But because of the greater simplicity of experiments with air, especially in pitot-tube velocity measurements, it is possible that new facts applicable to sand-water transportation may emerge from the study of sand-air transportation.

There would appear to be a closer resemblance between the behaviour of sand in air and that of drifting snow. For instance the peculiarly solid formation of "wind-slab" snow which G. Seligman describes in his book, 'Snow Structure and Ski Fields,' seems to have a very exact counterpart in a certain type of sand deposit which can be reproduced experimentally. Here again much might be learnt about snow-drifting from experiments made with sand, which is a far more convenient medium.

The particles dealt with are defined as hard grains small enough to be set in motion by the direct forward velocity of the fluid, but too massive to be seriously affected during their flight by the less violent velocities of the fluid's internal movements. Small particles of dust are seriously affected by these internal movements, but their behaviour is beyond the scope of this paper. As an example of the susceptibility of sand grains to wind motion, a fine grain of the size (0·25 mm. diam.) commonly found at the crests of dunes when shot into still air at a speed of 4 m./sec. (9 miles per hour), travels 20 cm. before its speed is reduced by 50 per cent.

Wind-driven, the sand grains move in bounds (or in "saltation" [2]), rising steeply into the air stream, and there being urged forward by the pressure of the wind upon them. By their weight they fall to the ground again, but with a high horizontal velocity component acquired from the air. On impact with

[1] Most of the results outlined here in the first four sections have already been described in detail in the Proceedings of the Royal Society, Series A, No. 892, vol. 157, pp. 594–620, December 1936; but the subject-matter of the subsequent sections is new. An account of the general type of motion of the sand grains, as surmised but not then experimentally verified, was originally read before the Royal Geographical Society and appeared in the *Geogr. J.* 85 (1935).

[2] This term appears to have been introduced by G. K. Gilbert in his well-known paper "Transportation of debris by running water," U.S. Geological Survey Prof. Paper 86, 1914, to describe the same bounding action of sand grains over the bed of a water-channel. In water however the height of the grain path is only some three times the grain diameter, whereas in air it may be fifty to a hundred times as great.

the ground they may either (1) bounce with but slightly reduced velocity off a pebble or large grain, and, rising high into the air, continue their journey in a series of bounds; or (2) splash into and end their flight in a surface of grains similar to themselves. In case (1) the rebounding grain may in a normal wind rise as high as 1 metre, and it may travel 8 metres or more down-wind before again falling to the ground. In case (2) the impact splashes up other grains a few centimetres into the air, and the range of these is quite small before they in turn strike the ground and splash up more grains. In both cases the moving grains have the appearance of a cloud. Though the bulk of the sand in the cloud passing over the surface of sand in case (2) moves very close to the ground, the visible top of the cloud is some twelve times as high. Plate I shows actual photographs of the motion in this case, together with some theoretical paths calculated by assuming the grains to be smooth spheres which rise with a given initial vertical velocity into the air stream.

There is also a general creeping forward of the surface grains along the ground, caused by the impact of the grains descending from the sand cloud. The rate of this creeping motion is about one-quarter that of the whole sand flow. Thus there are two main components of the total sand flow: the sand cloud and the surface creep.

It will be seen from the foregoing that the sand grains above the ground are not, in general, held in suspension by the air any more than is a thrown cricket ball, but derive their height from the upward reaction of the ground during a previous impact with it. The mathematical treatment used on the Continent (*e.g.* Exner, *Geografiska Annaler*, 1927, H. 1–2), whereby attempts have been made to explain dune and ripple formation by assuming gravity waves in a composite fluid of varying density consisting of air (or water) and sand grains in suspension, does not seem to be applicable. Nor does it seem possible in the case of air and sand to assume, as is done in current work on the transport of sediments by water, that the particles have the same forward velocity as the fluid surrounding them, so that the quantity of solids carried along can be expressed in terms of the velocity of the fluid and the density of the particle distribution in it. Both these assumptions would of course be permissible in the case of fine particles in true suspension.

On the other hand, since the motion of sand grains in air is a surface phenomenon, and since by definition our particles are independent of the eddies in the ground wind, it is reasonable to assume that the experimental conditions in a wind tunnel can be made to approximate fairly closely to those in the open.

The experiments were carried out in a specially constructed wind tunnel 30 cm. square in cross-section and 10 metres long, at the City and Guilds (Engineering) College, London. Plate II shows the general lay-out of the apparatus. Wind was sucked through the tunnel by a fan placed on the roof of the box A in which the sand settled, and whence it could be collected for re-use through the door B. The tunnel was divided into sections 1 metre long by air-tight hinged joints, and each joint was supported by a spring-balance. Thus by reading the changes in the total weight of each section before and after a timed run, the movement and rate of flow of the sand could be traced along the tunnel length. Wind velocities were measured with a small pitot

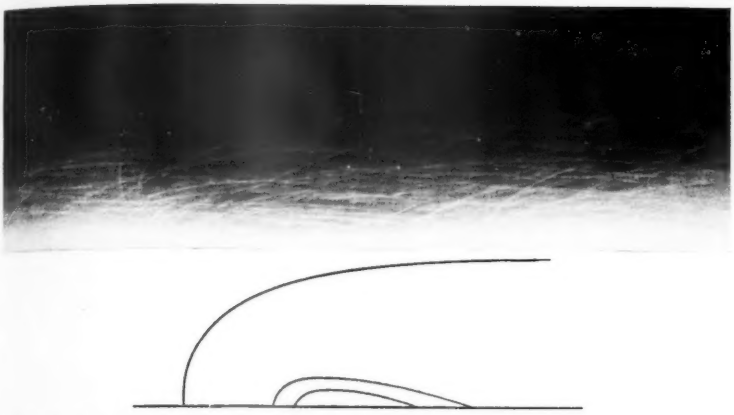


Plate I. Paths in air of sand grains of diameter 0·024 cm. with the calculated paths of smooth spheres in the same wind below

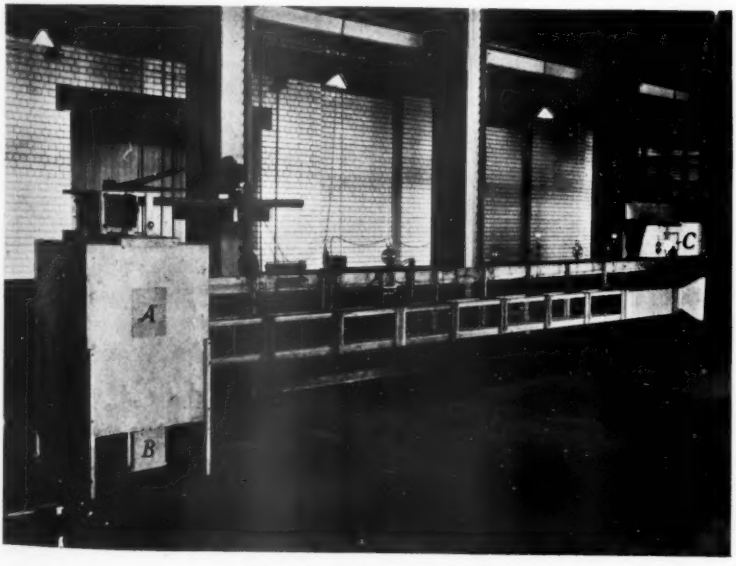


Plate II. Wind tunnel

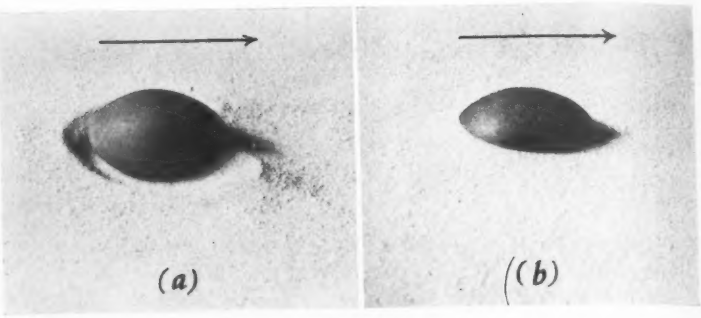


Plate III

Plate IV (a)

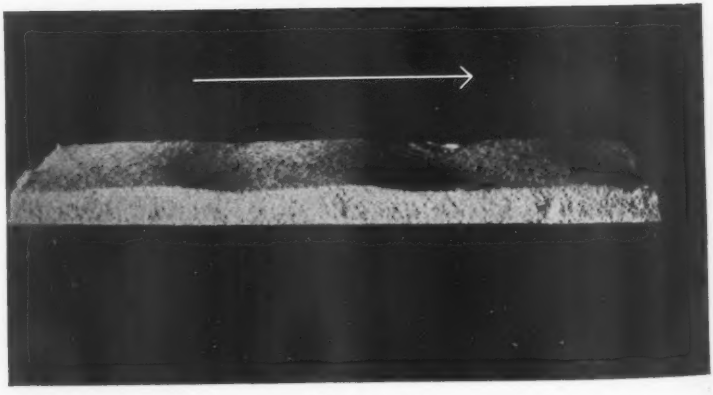


Plate IV (b)

or hypodermic syringe tube. From a reservoir C, also supported by a spring-balance, a stream of sand could be fed into the tunnel mouth. The sand to be used was spread in an even layer over the tunnel floor.

2. *The velocity of the wind close to an open, flat surface*

The whole phenomena of sand movement is so intimately bound up with the velocity of the surface wind, with the forces exerted by the wind on the sand grains and also with the resistance offered by the grains to the passage of the wind, that the distribution of wind velocity near the surface of the ground must be considered in some detail before we can proceed further.

The expression "velocity of the wind near the ground" has no meaning of itself, since the velocity varies according to the height above the ground at

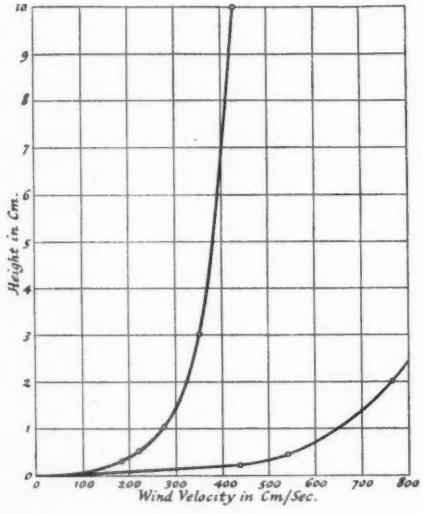


Fig. 1

which it is measured. At some level down among the pebbles, grass blades or other irregularities of the surface, the wind velocity must be zero; and from this level upwards it increases, very rapidly at first, and more slowly as the height of measurement is raised. Fig. 1 gives an example. Close to the ground the rate at which the wind varies with the height is controlled entirely by the nature and size of the surface irregularities, which, by dissipating the forward energy of the wind in the formation of eddies, exert a frictional force on the air moving over them.

By making certain mathematical assumptions concerning the nature of these eddies, Prandtl has succeeded in finding a working formula giving the velocity of any fluid near a boundary surface in terms of the magnitude of the frictional force on unit area of the surface (*i.e.* the surface drag), the height of measurement above the boundary, and the size of the surface irregularities. If v_z is the velocity at any height, z, τ is the surface drag, ρ the

density of the fluid, and k is 1/30 of the size of the surface irregularity, then

$$v_z = 5{\cdot}75\sqrt{\frac{\tau}{\rho}}\log_{10}\frac{z}{k} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and this remarkable formula is found experimentally to hold good for the velocity distribution near the surface in channels, in pipes or in the open, and whether the fluid is gas or liquid.

By representing the velocity distribution at different heights, not by the linear graph of Fig. 1, but by a graph in which the ordinate is the logarithm of the height, the curve of velocity becomes a straight line. Since a logarithmic scale has no zero, zero velocity in the new diagram is given by the point O at which the straight line cuts the ordinate. This point lies at the height k. In

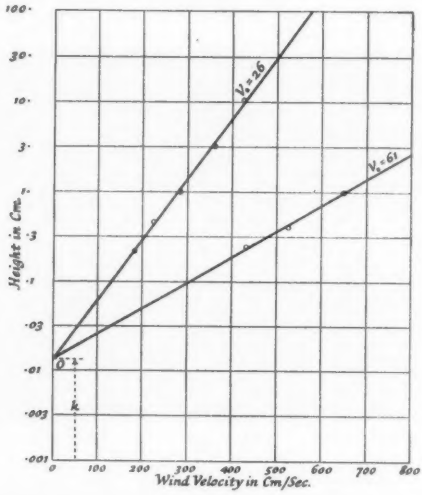


Fig. 2

Fig. 2, k is seen to be 0·015 cm., corresponding to a surface irregularity of diameter 0·015×30=0·45 cm., that of a small pebble.

If the measurements are made over the same surface when the wind strength is greater, another straight line or ray will result, passing through the same focus O but inclined at a greater angle to the vertical. On the other hand if the surface is changed to one composed of smaller grains, and the same pressure is exerted to urge the wind against the frictional resistance of the surface, the straight line representing the wind velocity distribution will retain the same inclination, but will be shifted bodily to the right so as to reach zero velocity at a lower level. In other words, the whole wind will move faster.

In what follows we shall find that the most important quality of any surface wind is not its absolute velocity with regard to the ground, but its rate of increase in velocity according as it rises above the ground. Diagrammatically the inclination of a ray in Fig. 2 is more important than its lateral position. For since the inclination is a measure of the ground force or drag which must

be overcome by the meteorological forces impelling the wind along, and since these forces are likely to remain constant over large areas, the inclination of

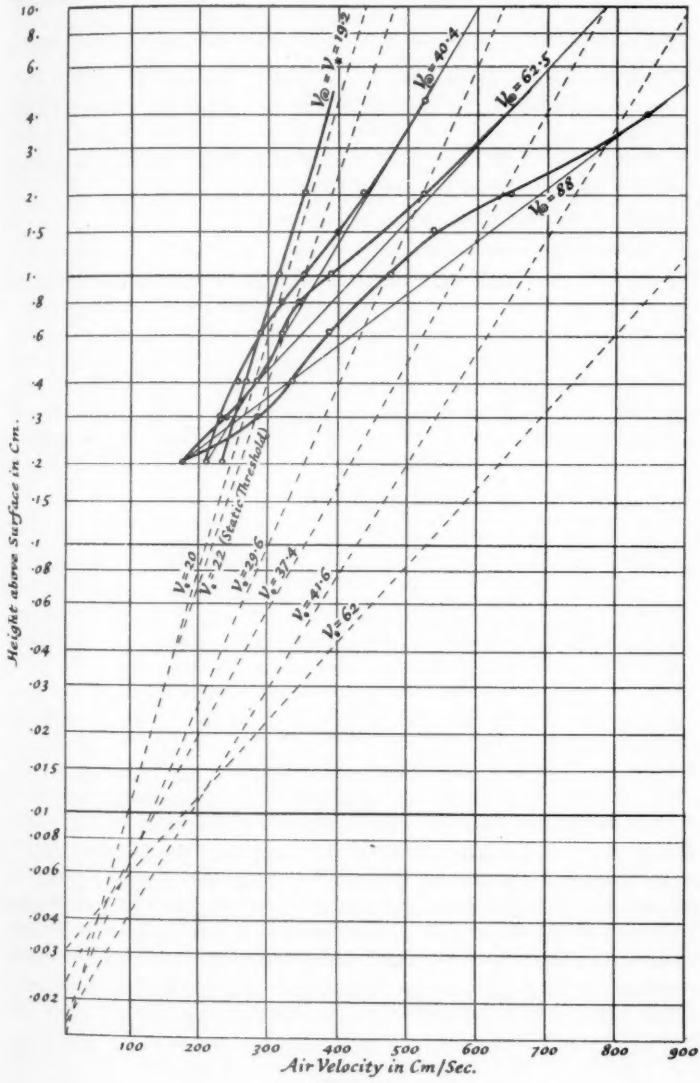


Fig. 3

the ray, or the rate of increase of wind velocity with height, is also likely to remain constant. On the other hand it is clear that close to the ground the

lateral position of any diagrammatic wind ray is determined entirely by the surface irregularity (the height k).

In equation (1) the inclination of the straight line is determined by the quantity $\sqrt{\frac{\tau}{\rho}}$ which is called the vertical wind gradient and is usually denoted by V_*. From it the drag τ exerted by unit area of surface is given by $\tau=\rho V_*^2$. V_* may be regarded as the inherent velocity of the wind independent of the height of measurement and of the surface roughness. Over any given surface it is proportional to the velocity v_z as measured at any given height z, and is equal to v_z divided by the constant $5{\cdot}75 \log z/k$.

3. *Wind velocity over a flat surface of loose sand*

If the surface consists of sand, the height k of the focus O will be lower than for pebbles, but provided the surface grains could be prevented from

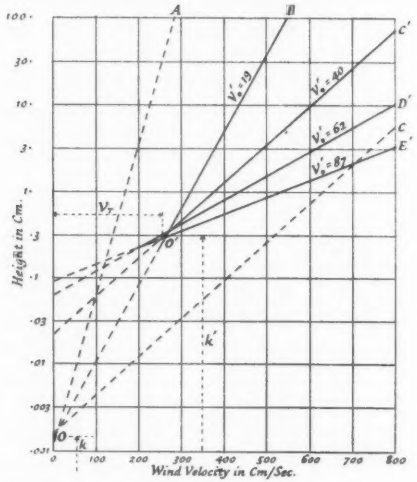


Fig. 4

moving, the velocity distribution of the wind over the surface would be similar to that just discussed. The sand can indeed readily be "fixed" by spraying with water mist, and the dotted lines in Fig. 3 show a set of actual experimental velocity rays for a fixed surface of sand of an approximately uniform grain diameter of 0·024 cm.[1] (sand of this size was chosen for experiment because it is representative of most sands found at the tops of dunes).

Now suppose that the surface is dry, and the sand free to move. The

[1] It will be seen that the value of k is somewhat greater than 0·024/30, which it ought to be if the surface irregularity were taken as the grain diameter. This is probably due to the surface being pitted with small craters a few grain diameters in size made by the impact of high-speed grains on the surface. Since however the velocities at these very low heights can only be deduced by prolonging the straight lines joining points found by measurements at higher levels (0·2 cm. and over), some margin for error must be allowed.

heavy lines in Fig. 3 show the new velocity distribution of the wind. In Fig. 4 they are shown more diagrammatically for the sake of clearness. As the wind gradient increases from still air (vertical ray through O) to OA and beyond, there is at first no change from the previous condition, but at OB a critical gradient is reached which is the threshold of the sand movement. At all wind gradients above this a complication sets in which greatly modifies the simple Prandtl velocity distribution: the surface itself begins to move.

If the wind gradient is increased beyond OB, the effect of the moving grains upon the air is as if the roughness of the surface were to increase with the rising wind; so that the height k rises. The wind velocity measured very close to the surface—closer than 0·3 cm.—actually falls as the velocity higher up increases;[1] and at a height of about 0·3 cm. the wind velocity is maintained at a constant value at all wind gradients above the threshold, however great, by a corresponding increase in the drag caused by the moving sand grains.

The velocity rays therefore, instead of passing through O as before, now pass through a new fixed point O′ of height k' where the velocity is constant. As far as I have been able to measure it, k' seems to have roughly the same value, 0·3 cm., for all nearly uniform sands. The constant velocity at this height is also the threshold velocity required to maintain the sand movement down-wind of a freshly disturbed patch of sand. It depends on the diameter of the surface grains, and for a uniform sand is given by [2]

$$V_T = 0{\cdot}47\sqrt{\frac{\sigma-\rho}{\rho}gd}\,.\log\frac{30\,k'}{d} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where σ and ρ are the densities of sand grain and air respectively and d is the grain diameter.

It should be noted that the threshold wind here dealt with is somewhat smaller than that required to move an undisturbed sand surface. I have called it the "dynamic threshold." It is the wind under whose action an initial bombardment of sand grains on the surface will just give rise to sufficient new flying grains to continue the process of sand movement indefinitely down-wind. The upper, or "static threshold," is that required to move the grains in the first instance by direct wind action alone. This static threshold wind is not very definite since it depends on several factors: on the former history of the surface and the extent to which sand removal has collected a protective layer of the biggest grains on the surface; on the surface turbulence of the wind, which may be accentuated by a large temperature difference between the air and the sand surface; and on the length of the exposed surface. As regards this last, the initial movement never starts at the most up-wind end of the surface, but always at the down-wind end, the point of initial move-

[1] It is instructive, as a practical demonstration of the great reduction in the surface wind velocity during violent sand-driving, to place a splinter of wood or a sprinkling of confetti on the surface after the wind has been started. Many of these objects, instead of being swept up immediately and blown away, are seen to creep jerkily along the ground exactly as one sees small articles carried off by ants. This is undoubtedly the explanation of the startling fact so often observed that bits of paper and other light objects often remain indefinitely on the top of a dune without being blown away.

[2] The coefficient was given in my paper to the Royal Society as 0·43. Recent determinations indicate that 0·47 is a more accurate figure.

ment shifting up-wind as the wind gradient is increased. A possible explanation of this is that it is a probability effect, and that the chances that an exceptionally violent wind eddy will disturb the first grain depends on the number of grains exposed. Over the experimental distance of 10 metres the ratio of the static to the dynamic wind threshold gradient for sand of 0·024 cm. diameter was as 1·15 to 1. For coarse sand of 0·1 cm. the ratio increased to 1·4 to 1. For very fine sand of 0·008 cm. the two gradients appeared to be the same. The variation of threshold wind with grain size will be referred to again in section 14.

Disregarding the kinks in the velocity rays shown in Fig. 3 and treating them as approximate straight lines (Fig. 4) at higher levels, Prandtl's rough surface law already stated can be modified to represent the new velocity distribution by putting

$$v_z = 5{\cdot}75 V'_* \log_{10}\frac{z}{k'} + V_T \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where k' is a constant experimental height whose physical meaning is not quite clear but is probably connected with the ripple amplitude, and V_T is the threshold wind velocity at this height and is a function of the grain size as given by (2). $V'_* = \sqrt{\frac{\tau'}{\rho}}$ where τ' is now the drag due to the sand movement. As the wind gradient increases, the wind velocity at the actual surface tends to become very small indeed, so that the old surface drag τ becomes entirely replaced by the sand drag τ'.

4. *The wind velocity—sand-flow relation*

The kinks in the wind velocity curves in Fig. 3 provide a valuable indication of the level at which the forward momentum of the wind is transferred to the

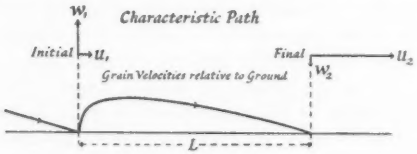


Fig. 5

sand grains; and direct measurements of the distribution of density of sand in the cloud at various heights confirm that the bulk of the sand in the cloud moves at about the same height as that of the kink for any given wind gradient. Calculations of the movement of ideal spheres show that these receive the bulk of their momentum very near the top of their path, whatever the height and range of that path may be. Hence by choosing a theoretical path whose height corresponds with that of the experimental kink, and replacing the heterogeneous collection of real grain paths by this ideal one, we have an ideal simple sand movement characterized by a path of one height and range, which will exert the same drag on the air as the real movement.

Fig. 5 shows such a characteristic path and its initial and final velocity components. It is clear that in a given wind the height and range of the

grains depend on the initial velocity W with which the grain is ejected from the surface. Since the ejection is caused by the impact of another grain whose velocity of impact depends on that of the wind, I have assumed the velocity W to be proportional to V'_*, so that $W=BV'_*$ where the coefficient B characterizes the type of impact of the bombarding grains with the surface.

Now in calculating the theoretical paths of the ideal spheres, it appears that the relation $W=\frac{gL}{U_2}$ holds to within 5 per cent. error for all grain paths and for sand grains of all sizes, where L is the path range and U_2 is the final horizontal velocity. We therefore have $\frac{L}{U_2}=\frac{BV'_*}{g}$. From considerations of momentum it can be shown that if all the grains were to follow one characteristic path, the mass of sand q_s in saltation passing per second between two fixed vertical boundaries unit distance apart is given by $q_s=\tau'\frac{L}{U_2-U_1}$. Hence, if we neglect U_1 the initial horizontal velocity of the grain as being negligible compared with U_2

$$q_s=\tau'\frac{BV'_*}{g}$$

But by definition $\tau'=\rho V'^2_*$

Hence finally $$q_s=B\frac{\rho}{g}V'^3_* \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Since the sand of the surface creep derives its forward movement from the bombardment of the saltation, and not directly from the wind, it contributes nothing to the drag. As mentioned in section 1, the surface creep is approximately equal to $q/4$, so that q_s should be approximately 0·75 of the total observed sand flow q leaving the tunnel under a wind whose gradient is V'_*. In the above reasoning several theoretical assumptions have been made as to the mechanism of the sand movement, and it would be very strong confirmation of the general validity of the theory if equation (4) gave even approximately correct values for q_s. The following table shows some experimental values for V'_* and q_s together with values of B as calculated from them. These values of B should be compared with the value 0·8 originally found from the interpretation of the height of the kink in the wind velocity curves without any reference to the sand movement.

V'_*	40	50	62	87
$q_s=0{\cdot}75\times$observed flow . .	0·09	0·19	0·33	0·91
$B=\frac{gq_s}{\rho V'^3_*}$	1·12	1·21	1·11	1·11

The constancy of B shows that the cubic relation is well borne out by experiment. That the sand flow as experimentally measured is rather larger than the theory suggests is probably due to the grains of the sand used not being identical in size. For though the sand was as uniform as possible, the grains ranged from 0·018 to 0·03 cm. diam., and as impact phenomena are concerned with masses, the variation in mass between the biggest and smallest grain was as great as 4·5 to 1. Thus even here an appreciable bouncing must

have occurred, and the effect of this would have been to increase the initial upward velocity of the grains. Experiments with sand of the same mean grain size but of a wider size variation show that B does increase as the grain size becomes less uniform.

As the coefficient B depends on the impact conditions, if these were identical for all grain sizes, the sand flow q should be the same for all uniform sands. Actually I find that q is smaller for very fine sands. Precise measurements with sands of large diameter were not possible in the tunnel for reasons given in the next section. For grain diameters of the order of our standard sand q appears to vary approximately as the square root of the grain diameter. It is well known that fine sands are relatively sharp, and it may well be that the impact conditions are not quite the same as for sands of larger grain size.

Introducing an empirical coefficient C, the experimental sand flow is given by

$$q = C\sqrt{\frac{d}{D}}\frac{\rho}{g}V_*'^3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where D is the mean diameter of the standard 0·024 cm. sand, d that of any other sand, and C has the following values: 1·5 for a nearly uniform grade, rising to 2·8 for a sand with a wide range of grain size.

From equation (3), q can be expressed in terms of wind velocity as measured at any height z by

$$q = C\sqrt{\frac{d}{D}}\frac{\rho}{g}\frac{(v_z - V_T)^3}{5{\cdot}75\log_{10} z/k'} \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

so that if the wind velocity is measured at some constant height, the sand flow varies as $(v_z - V_T)^3$ where V_T is a grain size constant, which for fine dune sand may be taken as 2·5 m./sec.

5. *Fluctuations in the rate of sand flow. Lower limit to the size of dunes*

During the experiments the unavoidable end-effect of the tunnel mouth brought to light some interesting phenomena.

If no sand enters the mouth, the sand flow there is zero. But at a point near the mouth, the distance from it decreasing with increasing wind gradient, the first grains are dislodged by the direct pressure of the wind, and move forward. Each of these grains disturbs other grains, which, in their turn, begin to move. The sand flow grows as the distance increases from the point at which movement starts. As a consequence, the wind velocity close to the surface is less further down the tunnel than at the mouth. For example, according to the dotted line OC of Fig. 4 the velocity is 5 m./sec. at a height of 0·3 cm. ($=k'$), whereas the increasing sand resistance ultimately causes the wind distribution OC to change to O′C′, so reducing the speed 2·5 m./sec. at this height.

But there must be a lag at any given point between the sand flow there and the full effect of its drag upon the wind velocity; for the drag, originating in the tiny eddies in the wake of each individual sand grain as it moves backwards relatively to the air, must take time to spread through the fluid and so reduce the general velocity of the air molecules. Consequently at the point at which the sand flow reaches a value equal to the steady rate it will

eventually attain, the air is still moving faster than the corresponding steady velocity that it will eventually attain. Hence the sand flow increases for some further distance. The wind where this is happening becomes overloaded with sand, and its velocity is rapidly reduced. The surcharge of sand then leaves the cloud and is added to the surface.

The above fluctuation usually goes through a second cycle further down the tunnel before the régime conditions ensue. This second cycle is feeble compared with the first, due no doubt partly to the damping effect of the drag of the sides and roof of the tunnel. There may be conditions in the open under which such fluctuations might increase instead of dying away. In general however it may be said that any change in the rate of sand flow produces a fluctuation down-wind of it—usually a removal of the surface followed by an accretion of sand.

Fig. 6 shows an example of the fluctuation in the rate of sand flow along the tunnel. In curve (a) there was no initial inflow of sand; in curve (b) the inflow was less than the ultimate rate; and in curve (c) the inflow was greater. The wind was kept constant in all three cases.

The sand used in the above experiment was the same nearly uniform grade

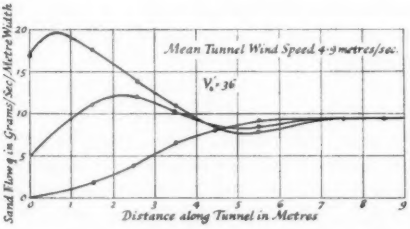


Fig. 6

of mean diameter 0·024 cm. When a sand of larger grain was tried, the distance required before the régime conditions were established was longer. With a sand of 0·1 cm. diam. the flow showed little sign of approaching its maximum value even at the end of the tunnel 10 metres from the mouth. This increase of the wave-length of the flow fluctuation is rather to be expected; for, given equal flow rates, the sand is carried in more massive grains which are spaced further apart in the air, so that the drag eddies due to each grain will take longer to spread through the body of the surrounding air.

In the case of a mixture, where fine grains bounce off bigger ones and the height of the sand cloud is consequently greater, there are indications that the wave-length becomes very long. I think it probable that the well-known large-scale wave effect of a chain of dunes, whereby crests succeed each other at regular intervals, is due to this lag between a change of surface and its reaction on the air. For there is always a pronounced change of grain size and surface texture between the saddles and the crests. The existence of this lag also very probably explains why attempts in the field to make artificial small-scale dunes have failed. They have not been big enough to extend over one complete cycle of the sand-flow fluctuation. It may be significant that

the smallest true dune found in the field is about the same order of size as the fluctuation cycle produced in the tunnel.

6. *Lowering of the surface. Undercutting round isolated obstructions*

It is important in what follows to obtain a clear picture of the conditions of sand flow and wind velocity at places where the surface is being lowered, *i.e.* where the sand is being removed and therefore where the sand flow is increasing.

A sand-driven surface is being lowered when more grains leave a unit area than arrive on it in a given time. Lowering takes place because the surface wind velocity exceeds the threshold velocity for the surface grains, and so raises more grains into the sand cloud than were previously in it. The surface wind velocity is high because, up-wind of the point considered, there has not been sufficient sand in saltation to provide the drag necessary to keep the wind velocity down to its threshold value. Thus removal must take place in any surface of exposed sand where, immediately up-wind, the quantity of exposed sand is limited or has become exhausted. Removal also occurs in places where the sand available is unlimited, if the wind velocity is locally raised, *e.g.* by swirl round the sides of an obstruction. Lastly, removal occurs even when the surface wind remains constant, if the wind arrives at a place where, by some means, the surface composition allows of a greater sand flow for the same surface drag.

Since a removal of sand from the surface is synonymous with an increase in the sand flow over the surface, and since the sand flow is, for a given wind, limited in value, it is clear that sand removal must be a strictly local phenomenon and cannot occur at any one time over a long distance down-wind. The removal area may however, and generally does, slowly advance down-wind as the sand supply at any one place is exhausted.

It is commonly thought that during sand-driving any object such as a stone placed on the sand surface must always produce the well-known saucer-shaped excavation around itself, owing to the swirl of the wind past its sides. This is not always true, though on calm days, when perhaps one is more observant, it is usual to see such excavations.

The undercutting only occurs during removal conditions, which may be caused by the stone itself or independently of it. It is most pronounced when the wind is just below the static threshold gradient, so that while no sand is arriving from up-wind, the increased velocity of swirl is above the static threshold, and therefore removes sand from around the base of the stone. The sand flow once started carries on down-wind. It is the result of this condition, which occurs every time a sand-driving wind drops to a calm, that is usually seen. Plate III (a) shows the undercutting round a small stone placed in a position in the tunnel where the sand flow was growing.

Plate III (b) shows a photograph of the same stone in the same place a few seconds after the sand supply had been increased. The excavation rapidly filled up, and the surface sand creep, instead of shrinking away from the stone, now seemed to bank up against it like river water against a bridge pier. When the sand supply was increased above the régime rate, the stone was slowly buried by the rising surface.

The experiment was made of placing two similar stones in the sand stream, one behind the other. Under removal conditions the down-wind stone was partially shielded by the other from the eroding effect of the sand blast, so that the lower stone was less undercut. Under other conditions, the lower stone was again shielded, but this time from the surface sand creep. It therefore tended to be less sand-surrounded than the upper one.

7. *Movement over a sand surface containing immobile pebbles. Possible increased sand flow*

The experiment was made of mixing the uniform sand with a small proportion of pebbles 4 mm. in diameter. A steady wind just above the threshold strength was passed over this. As the sand was carried off down-wind more and more pebbles were exposed and these became increasingly denuded, projecting further and further out of the surface. These projecting pebbles gradually formed a wind shield, which tended to prevent further removal of sand. Eventually no more sand movement took place, the sand grains being completely protected. Even when a small flow of sand was supplied at the tunnel mouth—the wind remaining the same—the spring-balance readings remained constant, showing that no further changes took place in the loading of the surface. The surface was completely stable for that particular wind.

The wind was now raised. A fresh layer of sand was removed, and the surface still further denuded till a new stable condition was reached, when the sand movement again ceased.

When the wind was lowered and sand slowly supplied at the tunnel mouth, the surface tended to build up once more, sand being deposited in the hollows between the pebbles till a new stable surface was formed such that the sand was only just screened by the now more submerged pebbles. To give a concrete instance of the degree of protection afforded to a sand surface by a sprinkling of pebbles, a surface of fine sand, which would be moved if bare of pebbles by a wind of 4 m./sec. as measured at a height of 10 cm., was completely protected from a wind of 8 m./sec. by a scattering of pebbles 4 mm. in diameter distributed so thinly that only 10 per cent. of the surface was covered by them. A pebble surface can thus be regarded as a reservoir in which sand can be stored during a gentle wind, and from which it is removed by a stronger wind.

A very important result of this experiment emerged from measurements of the rate of the sand flow during the period immediately following a sudden increase of wind strength. Now in the stable condition the surface may be considered as being composed wholly of pebbles. The wind velocity distribution will therefore be very like that shown in Fig. 2, which was drawn for a surface irregularity whose grain diameter was 4·5 mm. When the wind is raised, and sand passes over the pebbles, the conditions are no longer the same as those we have hitherto been dealing with. The grains do not now splash into the loose sand surface, but bounce violently off the pebbles, rising into the air with an upward velocity far greater than before. Now we saw in section 4 that for a given saltation sand flow q_s the drag should be given by $\tau' = q_s g / W_1$ where W_1 is this upward velocity. Hence we should expect that the drag would be considerably less when the sand passes over the pebbles

than when it passes over its own uniform loose surface. Conversely, for a given drag or a given wind gradient the sand flow q_s should be greater. Measurements of the sand flow confirmed this. The sand flow over the pebbles was nearly double that which, in the same wind, took place over the former loose sand surface.

In the case of mixed sand the flow is already intensified, since the smaller grains bounce off the larger ones. There is thus less scope for the action of pebbles, and actually, if the range of grain size is sufficiently wide, the pebbles appear to have no effect at all.

8. *Consecutive surfaces differing in type. Wind velocity changes at the boundary*

We are now in a position to consider the important case in which a wind passes first over a normal pebbly desert surface and then over a flat patch of open sand of nearly uniform grain size—an incipient dune. These conditions were imitated in the tunnel by covering the floor with a layer of fine, nearly uniform sand, and then scattering pebbles over it. The down-wind half of the floor, except for the last metre, was then covered with a further layer of sand. The surface consisted therefore, as can be seen in Fig. 7, of 5 metres of pebbles, followed in turn by 4 metres of sand and 1 of pebbles.

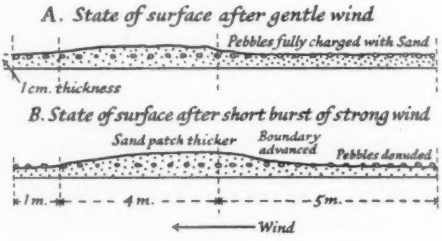


Fig. 7

Under a gentle wind the sand movement started first near the tunnel mouth, but as the pebble surface became stabilized this starting point moved down the tunnel till it reached and passed the boundary between pebbles and open sand. It then remained stationary about 2 metres down-wind of the boundary. The sand at and near the boundary was subsequently quiescent; removal was a maximum 2 metres further down, and became gradually less as the sand flow approached its régime rate. The lower boundary of the open sand advanced slowly down-wind, covering the pebbles. In effect, the sand patch was extending down-wind at the expense of its thickness.

The wind was now suddenly increased to a velocity at 10 cm. height of 10 m./sec. The sand flow over the pebbles started at a maximum value, and slowly fell as denudation proceeded. The initial intense sand flow piled itself up on the sand boundary, which actually moved up-wind. A heavy deposition took place over the sand surface from the boundary to a point some 2 metres down-wind of it. As the oncoming sand flow decreased in quantity, the boundary began to recede down-wind, being eroded away by the bombarding grains from the remaining available sand from among the pebbles. Accretion continued to take place further back, but now at the expense of the

sand at the boundary. When the pebble surface became completely stable, the boundary was left undisturbed, as before, but removal continued further down at a more rapid rate.

That sand accumulation is found to take place during a high wind but not during a gentle one is a little unexpected; but it appears inevitable if we consider the wind-velocity picture in the light of the preceding experiments, particularly since the velocity gradient of the wind tends to remain the same as the wind passes from one surface to another, though its absolute velocity changes with the surface.

In Fig. 8, P represents the height of zero velocity when the wind moves over the pebble surface; P is therefore the focus of the velocity rays. O is the corresponding height of zero velocity for the sand surface for gentle

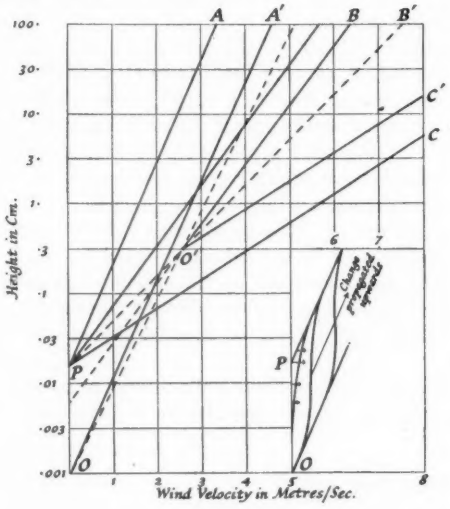


Fig. 8

winds when sand is not moving. O′ as before is the focus to which the velocity rays converge during sand-driving. The threshold wind distribution is given by the line OO′.

Consider a very gentle wind PA as it passes from the pebble surface to the sand surface. The lowest layer of air is the first to be affected by the changed conditions, for the level of zero velocity must drop abruptly from P to O. The air at the level P which was stationary now begins to move. As the wind advances over the new surface the change in the velocity distribution is propagated upwards to the higher layers (Fig. 8 inset). The general effect is that the whole ground wind is allowed to speed up because it blows over a smoother surface than before. But since the new ray passes to the left of O′ the velocity at the height k' is less than V_T, and no sand movement can take place.

Towards the end of the first part of the experiment just described, the

wind was not strong enough to move the sand on the pebble surface, but could do so on the open sand further down. The ray PB represents the velocity distribution over the pebbles. As before, when this wind reaches the open sand the velocity distribution tries to advance to a parallel line through O. But owing to the onset of the sand flow, it cannot advance beyond the line O′B′.

The subsequent high wind is represented, over the pebbles, by the ray PC. Since, over the open sand, no ray can pass to the right of O′ owing to the drag of the sand flow, it is clear that the surface wind must be checked at the boundary. Experimentally a violent disturbance of the sand occurred at the boundary, and by quick measurements of the wind velocity it was found that the back pressure caused a checking of the wind up-stream of the boundary. This no doubt explains the accretion up-stream and the consequent shift of the boundary up-wind.

At the down-wind boundary of the sand patch the wind begins to revert to its former distribution, slowing down from O′B′ to PB in the case of the low wind, and speeding up from O′C′ to PC in the case of the high wind. In the first case the sand streaming off the sand surface is deposited among the pebbles, so that the sand patch tends to extend down-wind. In the second case, the down-wind pebble surface is denuded to a stable condition, and the sand stream then passes on over it unchanged.

As previously pointed out, it is important in these experiments that the patch of sand shall extend far enough down-wind for the full effect of the sand movement to make itself felt by the air which is passing through it, and for the latter to adjust its velocity distribution to the new conditions. Otherwise its velocity might never be checked sufficiently for deposition to take place at all.

The same experiments were made with a sand of a wide range of grain size. It was found to be almost impossible to produce a deposit with such a sand.

9. *The conditions for dune growth*

It is not difficult to understand how sand may accumulate in a large tract of country to form dune fields or sand seas. One need only postulate a local climatic condition by which the sand-bearing wind becomes weaker when it reaches that particular area, *i.e.* a wind which at any given time varies in strength from place to place. Such a wind, with its consequent deposition of sand, can easily be imitated on a small scale. We have but to give the tunnel a local enlargement of cross-section in which the general wind speed is less than elsewhere. But this simple explanation of sand accumulation becomes untenable when applied to the growth of individual dunes, which not only exist on far too small a scale for climatic changes to be effective between one end of a dune and the other, but which repeat themselves in endless succession. For this we have to seek a mechanism by which a wind that is locally constant in gradient from place to place at any one time tends to concentrate sand in certain small selected spots.

If a dune is growing, it is obvious that the wind must be bringing more sand to it than it is taking away, and that there must be a primary source of

sand. Now a truly uni-directional wind, even though it vary in strength from time to time, as the experiment in the last section suggests it must, can clearly never cause a dune to grow unless the source is supplying sand at a rate (per unit width of country) greater than the régime rate at which sand is blowing off the dune. This is hardly possible. The wind must therefore vary in direction, as in nature it always does.

Fig. 9 illustrates how the experimental transient sand accumulation described in the last section might work under real conditions. Suppose that the whole area of the figure is a pebbly desert, or a sea or river shore of coarse grit, and let S represent a patch of uninterrupted fine sand of nearly uniform grain size. The prevailing winds which are mild in character blow in the direction shown by the dotted arrows from a constant source of fine sand somewhere up-wind. The prevailing condition of the surface is therefore a slow drift of sand across the area, the pebbles being highly charged with it. All that is now required for the progressive growth of the sand patch S

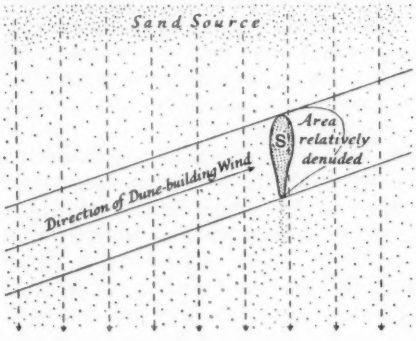


Fig. 9

in mass is that occasional gales of strong wind blow from any other direction than the prevailing one.

For example, if the gale blows in the direction of the heavy arrow, the stored sand in the pebble strip is available for dune building as was the freshly charged pebble surface in the wind tunnel experiment. The sand flow reaching the patch from over the pebbles tends to exceed that leaving the patch. Denudation of the strip (and, of course, of the surface on either side of it) begins far away at the outer edge of the whole sandy area, and slowly approaches the patch S as the gale continues. Thus, unless the gale lasts for a very long time, the surface immediately up-wind of S remains nearly fully charged. During the subsequent long period of gentle wind from the direction of the sand source, the deficiency in the charge of the surface is made good, ready for the next gale to sweep some of it up on to the dune S. During this period, too, the dune tends to string out in the direction of the dotted arrows at the expense of its acquired accretion of mass.

Since during the gale the dune has collected a portion of the sand which has been driving down the strip, the surface of the ground immediately to leeward of the dune is left partially denuded. For some distance to the leeward,

in the direction of the gale wind, conditions are adverse to the growth of any second sand patch which might exist there.

Given an unlimited sandy surface up-wind of the patch S, it is clear that its rate of growth in mass will depend (*a*) on the wind: the gradients and relative durations of the sand-supplying and the dune-building winds; (*b*) on the surface: its capability to pass over itself a sand flow exceeding the régime flow over the sand patch.

If q_1 is the sand flow over the pebble (or other rough) surface for a given wind gradient V'_*, and q_2 is the régime flow over and away from the sand patch for the same wind gradient, then the rate of growth of the patch, *i.e.* the weight of sand deposited on it per unit width per second, is $q_1 - q_2$. Since both rates of flow are functions of V'_*, the amount of absolute growth over any period will be given by $\int\{F(V'_*) - f(V'_*)\}dt$. Now $f(V'_*)$ has already been found experimentally (equation (5)); $F(V'_*)$ depends on the size and spacing of the irregularities of the up-wind surface and also to some extent on the degree to which the previous wind has filled the interspaces with sand. There is no reason why further experiment should not produce a fair idea of $F(V'_*)$ for various typical desert or other surfaces. Then, provided that adequate wind records were available, deductions could be drawn concerning the past and future movements and growth of the dunes in any required area.

An example of the rate of growth of the experimental sand patch in the tunnel may be of interest. The wind velocity measured at a height of 10 cm. over the pebble surface was 8 m./sec. This reduced the 5 metres of up-wind pebble surface to stability in three minutes. During that period q_2 averaged 46 grams/sec./metre width, and q_1 as measured at the up-wind boundary averaged 60 grams, so that the rate of accretion was 14 grams/sec./metre. Of the sand in movement therefore nearly 25 per cent. was deposited. Since q_1 began at a maximum and dropped as denudation proceeded, it seems that had the pebble area been longer, q_1 would have continued at the maximum rate for the whole period, and the proportion deposited would have been higher. The weight of sand lost by the pebble surface amounted to 2 kg./metre^2.

As regards the optimum conditions for dune-building, it would appear from Fig. 8 that there is a critical wind gradient given by the line joining P and O′ such that the wind is neither checked nor speeded up when passing from the pebbles to the sand. A wind of this gradient, blowing from the direction of the sand source, charges the pebble surface to its maximum storage capacity. Thereafter any higher cross-wind adds sand to the dune, provided (*a*) that it does not last beyond the time when the up-wind storage area is exhausted; and (*b*) that it does not blow so hard that the pebbles of the up-wind surface are set in motion and driven over the incipient dune. If this happens, they may so alter the conditions that q_2 rises to a value equal to q_1. In this event no more dune-building can take place; the dune will be killed. On the other hand a wind lower than BO′, of strength between PO′ and OO′, tends to elongate the dune down-wind at the expense of its mass.

It should be possible to find experimentally the actual desert values for the height of P, along with the values for q_1. In the meantime, it is encouraging

that for the position of P corresponding to the not unpractical assumed condition of small pebbles, the critical wind which emerges from the theory has the reasonable value of 6 m./sec. as measured at 10 cm. height.

Since the height of the point P is a measure of the size of the stones on the desert surface, it will be seen from Fig. 8 that the more stony the ground the greater must be the gradient of the critical wind below which no dune-building can take place, and in general the less frequent will be the dune-building winds. A surrounding surface of small pebbles therefore would seem to be more favourable to dune growth than a stony one.

10. *The prevailing sand-driving wind. Computation of its direction and of the resulting long period mass movement of sand from meteorological data*

It appears from the ideas considered in the last section that the direction of the long desert dune ranges is likely to indicate only the prevailing direction of the wind, exclusive of storm winds. The direction in which the total mass movement of sand is taking place will not in general coincide with it. (Though I can find no evidence of any sideways movement on the part of the great dune ranges themselves, the direction of the general sand drift may well be manifested by the slow formation of new parallel ranges to leeward.)

Disregarding the local disturbing effects of existing dunes and other surface features on the ground wind direction and on the general sand movement over large areas, the prevailing sand-driving wind direction over any area may be defined as coincident with the direction of flow of the sand mass in that area. This, together with an approximate figure for the resulting annual mass displacement of sand, should be capable of computation from ordinary meteorological data.

Wind records are available in the form of strength and direction as measured at equal intervals of time and at a fixed height above the ground. Unfortunately the vertical distribution of wind velocity is usually much disturbed at the place of measurement by surrounding buildings, fences, etc., so that the velocity at the height of measurement differs appreciably from that at the same height above open country. Nevertheless, it should not be difficult by measurements made in open country nearby to arrive at suitable correcting factors.

It has been shown in section 4 that the displacement of sand per second in the direction of the wind is given by an expression of the form $q=b(v-a)^3$. Taking the coefficient C in equation (6) as 2·8, and a standard height of measurement of 1 metre, b would become equal to 0·025 metre^{-4} kg. sec.^{2}; a reasonable value for the threshold velocity a would be 2·9 m./sec. If t is the standard period in seconds between meteorological observations, the mass of sand moving past a fixed point in the recorded wind direction will be given by $m=0{\cdot}025(v-2{\cdot}9)^3t$ kg. per metre width per period. Negative values of $(v-2{\cdot}9)$ indicate calm periods when no sand movement takes place.

m is a vector which can be split into north and east components $m\cos\phi$ and $m\sin\phi$ respectively, where ϕ is the leeward bearing of the wind during the period. By the summation of these components throughout the year we would arrive at a resultant vector M, giving the mass of sand displaced and the direction of the displacement. Such a computation carried out over a period

of years would be of distinct value, and if carried out for records from different stations in the same desert would indicate areas of minimum or zero M, which might be expected to coincide with existing sand-seas.

11. *Concentration of large grains by removal. Residue ridges*

The investigation of the factors governing the proportions by weight in which grains of different sizes are present in the sand mixtures which occur in nature is not yet complete. I hope to make this the subject of a future paper. It must be sufficient to state here that natural mixtures containing the different grades in proportions arranged according to a certain law appear to retain these same proportions when driven by the wind, but that when the size of the largest grade present is greater than a certain multiple of the mean grade, a small percentage of the largest grains is left behind whenever removal takes place. This percentage decreases as the wind is made stronger, but never quite disappears. Hence, except in the case of sand near the crests of dunes, removal involves concentration of the biggest grains on the residual surface.

I will describe here the behaviour of such a residual surface under the action of a wind carrying a cloud of fine grains, and the experimental formation of the so-called "giant ripples." These have often been described. Vaughan Cornish ('Waves of Sand and Snow,' chapter 2), calls them "Erosion Ripples." This more closely defines the mode of their formation, but erosion seems to imply the carving out of a coherent deposit, and since they may grow to 5 metres or more from crest to crest, the term "ripples" seems hardly appropriate. I prefer the term "residue ridges," which conveys better the origin of the concentration of big grains, whose presence is essential.

The experimental mixture used consisted of 90 per cent. sand of about 0·025 cm. diameter and 10 per cent. of 0·1 cm. diameter—four times as large. (The extreme grade usually found in a sand deposit is a little bigger, perhaps 0·15 cm.) This mixture may be compared with the pebble mixture of section 7.

A gentle wind just above the threshold value for the fine sand was made to blow. To begin with the surface was mostly fine sand, so that the surface wind settled down to its threshold velocity $V_T = 2{\cdot}5$ m./sec. A few big grains were pushed along the surface by the impact of the fine-grain bombardment, but V_T was far too small to enable any of them to rise into the sand cloud.

The effect of the big grains exposed on the surface was like that of the pebbles in section 7, to increase the flow of fine sand by tending to change the type of grain impact from a splashing to a bouncing one. But an increase in sand flow is synonymous with removal, and this, by exposing more and more big grains, proceeds at an increasing rate. It is here that such a surface differs from one containing immobile pebbles, for the big grains, as they were denuded of fine sand, were moved on by the pressure of the bombardment, and so could not form a protection against further removal. As long as the motive power of a bombardment of fine sand from up-wind continued, the removal went on.

Fig. 10 (a) shows the initial stage of the removal. The parallel lines represent a uniform bombardment of fine grains descending from the sand cloud.

Since the big grain A is exposed to a bombardment represented by three lines, it moves faster than the grain B, which, being partly screened by A, only receives two impacts in the same period. Similarly, grain C, which is closer to grain B and is still more screened by it, only receives one impact and moves slower still. The result must be that the big grains tend to collect together into ridges separated by bare spaces. These ridges can be seen experimentally to grow from very irregular transverse collections averaging 1·5 cm. apart to regular ridges of ever-increasing size. Plate IVa shows a photograph (approximately one half of the original scale) of a section of the ridges formed after a constant but feeble bombardment of fine grains had played on them for two hours. (The sand was fixed for sectioning by allowing a solution of water-glass to seep gradually into it from below without disturbing the piling of the grains. When dry the whole mass sets very hard.)

A diagrammatic section of the ridge is shown in Fig. 10 (b). To leeward of the crest A of the cap, the ridge outline consists of a steep slope at the angle of repose of the grains—about 35°. The slope then flattens out to B. Here the fine sand outcrops, and the surface is almost bare of big grains to the

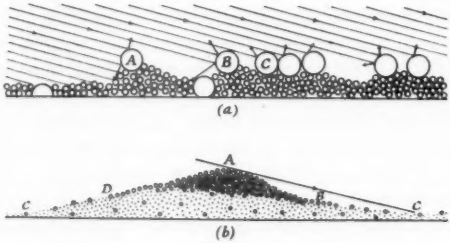


Fig. 10

bottom of the trough C. The inclination of the straight line AC is the same as that of the bombardment, about 14°. Hence the zone ABC is completely sheltered from the bombardment, and no grains are removed from it. From C to D the surface is still free of big grains, and, being unprotected, is exposed to the full eroding effect of the bombardment. This zone CD is the only portion of the ridge where removal can take place. From here, as the removal of fine grains from the original mixture continues, a fresh supply of big grains is continually being exposed. As the new big grains appear, they are driven slowly forward up the slope DA′.

This slope approximates to a plane surface. Its angle seems to be connected with the impact mechanism—the ratio of grain sizes and the strength of the wind. The big grains are driven up the slope one diameter at a time. They eventually reach the top A′ and then, tumbling over the crest, come to rest in the stagnant zone below. Unless the surface wind is strong, they have not enough momentum to carry them across the stagnant zone to join the next ridge. The cap therefore, receiving no additional grains from up-wind, can only grow by collecting grains which have been excavated from under its own ridge as it advances. Hence the continued growth of the cap and of the complete ridge associated with it depends on the continued fall of the

whole surface by the removal of fine grains from the original mixture. The proportions of the ridge seem to remain constant during its growth, being controlled by the angle of the windward slope, and by that of the incidental bombardment, which fixes the angle of the line ABC; so that if the rate at which the big grains are driven up and over the slope is a function of the intensity of the bombardment, and if this remains constant over the period of growth, the time taken by the ridge to advance a total distance x from its birth-place will vary as x^2. Thus for a ridge to attain the dimensions of the giant ridges sometimes found in the desert—5 metres wave-length—the time required must run into many months, if not years.

If the sand supply from up-wind, which is the only agent capable during low winds of moving the big grains, ceases to arrive, no sand movement takes place in any part of the area in which the residue ridges are established.

But if a limited sand supply is maintained, and the wind is increased, a change in the conditions takes place. For as the surface wind approaches the threshold velocity for the big grains (which it can now do since the surface is no longer composed only of fine sand), the big grains at the tops of the ridges have enough momentum, derived partly from the direct pressure of the wind, to carry them over the stagnant zone to leeward and on to the next ridge. This tends to stop the ridge from growing, for the big grains begin to move forward from ridge to ridge. When the wind velocity reaches the threshold value the big grains rise into the air to form the sand cloud, just as the fine ones did at the beginning. Being sixty-four times as massive, they bombard the ridge in front with such violence that it is broken down. The zone CD, being composed of finer and softer material, is cut away, and the ridge assumes a reversed aspect, the steep slope now facing up-wind. The ridges in breaking down split into smaller ones, and finally they cease to be ridges and reappear as ripples. Since, as we shall see in the next section, the wave-length of the ripple depends only on the wind strength, continued growth is no longer possible.

If, while the ridge is still well established and the wind is moderate, the supply of fine sand instead of being meagre is made plentiful, the fine grains, as might be expected, begin to deposit in the sheltered hollows to leeward of the steep faces. When this deposit has proceeded to a certain extent, a sudden change takes place. The big grains on the crests, instead of remaining stationary or gently tumbling over the lee slope, begin to roll forward rapidly over the new sand surface. They no longer tend to collect into ridges, but scatter evenly over the now growing sand surface. Finally the last traces of the ridges become submerged.

The conditions favourable to the formation of residue ridges may be summarized as follows: A continuous but limited supply of fine sand to act as the propelling agent; a deep sand deposit containing a proportion of big grains, which has been subjected to a long-continued removal process so that the residual surface consists of a relatively high percentage of big grains. These big grains should be bigger than the threshold diameter corresponding to the highest wind, but not too big to be moved slowly along by the impacts of the fine grains.

12. *True sand ripples*

A nearly uniform sand becomes rippled directly the wind is raised above the threshold value necessary to maintain the sand motion. As the wind increases so does the wave-length of the ripples, till, at a certain wind gradient, the ripples flatten out and disappear. The ripples once formed retain a constant wave-length indefinitely as long as the wind is kept constant. They retain their wave-length and shape whether the surface is being lowered, is growing, or is in régime. In the case of the experimental sand of 0·025 cm. grain size, the wave-length ranged from 2·4 cm. to 12 cm. The amplitude was very small, being only one-seventieth of the wave-length. Nevertheless the ripples were quite distinct when illuminated by a strong beam of light shining along the surface. (As it is impossible to obtain a truly uniform sand, it is an open question whether such a sand would ripple at all.) Using a very fine sand of maximum grain size 0·01 cm. and a very gentle wind, I have produced ripples as small as 0·5 cm. wave-length.

The section of the ripple is smooth and undulating (Plate IVb, approximately one half of the original scale), so that the surface, though rippled, remains practically streamlined. There is no evidence whatever for the existence of any fixed wind eddy in the shallow troughs, such as have formerly been called into being to account for the ripples.

When a surface of natural mixed sand has been in a true régime condition of flow, so that no surface concentration of big grains has been produced, or when the surface has been growing, the ripples are much the same shape and amplitude as for a uniform sand. They may be so flat as to be imperceptible in ordinary light. But in the removal condition, especially when the wind is gentle, the coarse grains concentrated on the residual surface at once begin to collect at the crests, though it is long before the biggest grains are excavated in sufficient proportions to give rise to the residue ridges described in the last section. The ripples still remain as ripples, for the crest grains are small enough to be carried forward from crest to crest with the surface sand creep. Hence the ripples will not for a long period begin the unlimited growth associated with the residue ridges. As has been pointed out by Vaughan Cornish in the book already quoted, the bigger the size of the crest grains, the greater is their tendency to collect together, *i.e.* the greater is the amplitude of the ripple and the steeper is the leeward slope. Finally, when the big grains cease to be carried over the stagnant zone to the next ripple, the crests start an uncontrolled growth, and become residue ridges. The creep of grains along the surface now ceases.

The physical causes which produce the true ripple and its definite wave-length have been the subject of many papers. In my paper in the *Geographical Journal* I gave a surmise of the causes in the light of the then unverified idea of granular bombardment. This surmise, as it now appears from experiments, gives the right explanation of the residue ridges rather than of the true ripples. As regards the wave-length of the true ripple, a new light may be thrown on it by the idea of the characteristic grain path dealt with in section 3. This path, it will be remembered, was the ideal path which, if followed by all the grains in saltation, would produce the same drag on the air as the real heterogeneous motion. It may therefore be regarded as the mean path of the

saltation. Its height was manifested by the height of the kink in the measured wind velocity curves of Fig. 3. Given the wind velocity impelling the grain forward, and also the grain's initial velocity of rise necessary to bring it to the required height, the range down-wind of the characteristic grain from the beginning to the end of its path was calculated. This range, for every experimental wind strength used, coincided almost exactly with the measured wave-length of the ripples formed during the same experiments.

These experiments were done with the nearly uniform sand. With a natural sand mixture the wave-length of the ripples formed during the partial surface concentration just described is longer, for the same wind gradient. This is completely in accordance with the idea that the wave-length is a manifestation of the characteristic path. For an accumulation of big grains at the crests increases the bouncing of the grains in saltation, so that their velocity of take-off is greater and their characteristic path correspondingly longer.

I now regard the ripples as a series of accumulations of surface grains resulting from small-scale fluctuations in the rate of the surface creep—a sort of concertina effect brought about by local variations in the intensity of the impelling bombardment. Such variations would arise from variations in the angle of impact, due to the undulating surface, causing more bombarding grains to issue from one point than from another. They would affect the surface and characteristic path range down-wind and would cause further undulations in the surface.

It may be that small-scale ripples are the result of fluctuations in the rate of surface creep; and large-scale dunes of fluctuations in the rate of the saltation sand flow overhead.

In a stream of water, at low speeds, surface creep appears to be absent, owing no doubt to the relatively feeble impacts of the grains in saltation. Hence the true undulating ripple does not form. The ripples are of the steep-faced type, and their wave-length is probably controlled by the fixed eddy in the lee of the steep face. In air on the other hand the eddy if and when it occurs has, by our initial definition of sand, little or no effect on the motion of the grains.

I have so far been able to produce only two artificial conditions under which no ripples occur, so that the surface is entirely smooth. The first has already been mentioned; it is that of a high wind whose velocity gradient is above a certain critical value. The second condition is that of the sedimentation type of sand deposit. This will be described in the next section.

13. *Types of particle deposition. Accretion, encroachment, sedimentation*

There appear to be three possible ways in which particles may be deposited from a fluid. In each case the deposit has a distinct mechanical texture and a distinct size grading of the grains.

Particles, sand or snow, may be driven by the fluid, air, or water in three ways. Only the finest can be carried in true suspension. The other motions, saltation and surface creep, involve repeated contact with the ground. Particles in saltation derive their forward motion direct from the fluid, while those in surface creep are driven along by the impacts of the particles descending from saltation. As we have seen, particles in saltation exert on the fluid a drag which

is a function of the fluid velocity gradient and of the type of the ground surface.

1. *Accretion.*—When the surface is flat, if either the velocity gradient is reduced, or the type of surface changes so that the particle flow is reduced, then there must be a deposition of particles on to the surface. Both saltation and surface creep, which is a result of it, are reduced, and particles from both come to rest. The surface grows evenly till a rounded and possibly rippled mound is eventually produced.

2. *Encroachment.*—When the surface contains a sudden drop, such as the lee slope of a dune or of a residue ridge, the saltating particles in the fluid continue their flight and reach the surface some distance beyond the drop. But the particles composing the surface creep which are being driven along the surface by the bombardment of the descending saltation drop over the crest into the stagnant zone, where they are sheltered from further bombardment. Here they pile up until their weight causes the surface of the slope to collapse as an avalanche. Thus the whole lee slope encroaches down-stream. The deposit, being drawn entirely from the surface creep, will contain the larger grades in a greater proportion than that in which they were present up-stream of the drop.

3. *Sedimentation.*—On the lee side of a rounded dune (whaleback) over which sand is drifting it is easy to imagine a condition in which particles from the main sand cloud are falling into a zone where the surface wind is below the threshold strength necessary to move the surface particles. Snow falling during a gentle wind is a more familiar example. The particles fall at a steeper angle than that at which true saltation particles strike the ground during drifting, and their forward velocity is too low to produce any surface creep on the part of the ground particles. In an expanding wind tunnel, where a sand cloud is made to pass into zones of weaker and weaker wind, it can be shown experimentally that at the point where the surface creep ceases owing to the lessening wind speed, and where sedimentation therefore takes the place of saltation or drifting, there also the surface ripples disappear.

14. *Firm and soft sand deposits. Guides to past history of the surface*

It has been noticed by most travellers in dune country that sand deposits, though superficially much alike, differ greatly in their resistance to a load such as a lorry wheel or a footfall. I have analyzed for grain size distribution many samples of sands taken from hard and soft places, but there seems to be little correlation between grain composition and firmness.

From field observations the only points which seem clearly established are (1) that a firm deposit is always made soft by an artificial disturbance of the original piling of the grains; and (2) that very soft sands only occur in the actual neighbourhood of dunes or in the paths of dune chains.

Now in the wind-tunnel experiments, deposits formed by accretion, *i.e.* by the general growth of the whole surface, whether of a mixture or of a uniform sand, were always exceedingly firm below a thin layer comparable in thickness with the ripple height. The only exceptions were in the cases of uniform sand of very large grain size, and sand composed entirely of grains so fine that they approached the texture of loess.

The firmness of sand accretion deposits in general is quite astonishing, and it is difficult to realize that there is no cementing whatever between the grains. The explanation seems to lie in the action of the surface creep in shifting each grain gently from place to place till it finally lodges in the most secure home between other grains.

I think there must be a very close connection between the firm accretion deposit of sand and the wind-slab snow formation which Seligman describes as arising when deposition takes place simultaneously with drifting. If this is so the peculiar firmness of the wind-slab may be due more to the piling arrangement of the snow granules than to cementation. The number of points of contact between grain and grain is greatly increased as the piling is made more compact.

In the case of encroachment the sand grains have reached their final resting-places by a series of avalanches. The piling is haphazard and very dilated, and the result is extremely soft.

Intermediate in firmness is the sedimentation deposit. A simple demonstration of the difference in firmness between two types of deposit can be made by examining the feel of two heaps of the same sand; the one a sedimentation made by dropping grains through a sieve, taking care that the sides never get so steep that avalanching occurs; and the other by pouring the sand

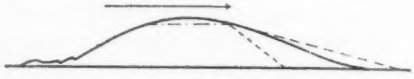


Fig. 11

through a funnel so that it comes to rest after avalanching down the sides of the heap.

In the desert the sand grains may reach their final resting-place by accretion or by encroachment, though sedimentation may also take place, especially when the wind drops suddenly after a sand-storm. A very firm deposit, provided it is not due to cementing by moisture, must be a sure sign of true growth. On the other hand a very soft deposit occurring in open country indicates that either (1) it has in the past been disturbed by living agencies such as the roots of herbage or the trampling of cattle; or (2) a dune has at some time or other moved over the place, and since that time the surface has not been built up.

We also have another indication of the past history of the deposit, for, as explained in section 10, the presence of well-established residue ridges shows that prolonged removal has taken place.

The case of a barchan dune provides an interesting illustration of these surface indications (Fig. 11). The barchan advances from left to right. Sand arrives from up-wind, and blows over the rounded top. Most of the saltation sand-flow of finer grains is carried over in the wind. The angle of descent is determined by the terminal velocity of fall of the grains, and should be not very different from the angle of the small-scale surface bombardment with which we have been dealing—about 14°. This sand therefore reaches the ground some distance beyond the foot of the slip-face whose angle is about

35°. The surface creep tumbles over the crest and forms an essentially soft deposit, which will, as the dune advances, form the main bulk of it.

The dune may be growing in bulk as it advances, or it may be shrinking. There may be occasions, after a violent burst of dune-building wind, when the windward surface has actually moved up-wind. Suppose that the normal state is an advance without change of bulk. The main mass of the dune below the level of the crest of the slip-face is continually being exposed on the windward side by removal, and this mass, being an encroachment deposit, is soft. Also, since a sorting of the grains has taken place at the crest, the main mass of the dune, especially towards the bottom, whither the biggest grains have rolled, tends to consist of a residual mixture such as we dealt with in section 10. At the extreme up-wind boundary therefore we should expect to find, and very often do find, residue ridges. On the other hand, the rounded top, above the level of the crest of the slip-face, must have been deposited directly out of the wind, and therefore should be relatively hard. If it is not, there is an obvious indication of a shrinkage of the dune. But if the windward slope of the dune is firm below the level of the crest, this would be an indication of growth.

15. *Very fine sands. The transition to loess*

Mechanical analysis of wind-accumulated sands for grain size show, when curves of percentage weight are plotted against grain size, that the peaks of such curves never occur on the small side of 0·015 cm. diameter, and rarely of 0·022 cm. diameter. Sand having a peak size nearest to this limit is found at the crests of dunes. The existence of this limit has long been a puzzle to me. Experiments with finer sand in the quantity required for the wind tunnel were hindered by the difficulty of finding a natural source of supply. I have however recently found a bed between Lymington and Brockenhurst, Hants, composed of pure white quartz grains, whose peak diameter is 0·01 cm. It is known locally as "soft sand," and, to the hand, has almost the feel of clay, although it contains hardly a trace of any impurity.

The physical properties of quartz particles, such as feel, angle of repose, and behaviour in a wind, change with curious rapidity as the size falls below the limit just mentioned. Below 0·01 cm. diameter, the angle of repose rises sharply, till clean dry grains of 0·005 cm. diameter will stand in vertical cliffs like those produced in flour or other fine powders. The presence of such grains in a mixture of coarser sand will also have the same effect. Since microscopically the grains are very little different in shape from the larger grains of dune sand, it seems that true cohesion must be the cause.

The variation of the threshold wind required to move sands of different grain sizes is shown in Fig. 12. Expressed in terms of the wind gradient V_*, the dynamic threshold wind given by equation (2) can be written:

$$V_* = \frac{0{\cdot}47}{5{\cdot}75}\sqrt{\frac{\sigma-\rho}{\rho}gd}$$

where σ is the density of quartz and ρ that of air. These can be taken as 2·65 and $1{\cdot}25 \times 10^{-3}$ respectively. Thus the dynamic threshold wind gradient is given by $V_* = 120\sqrt{d}$ cm./sec.—a straight line if plotted on a scale of $\sqrt{d}$

But this relation only appears to hold for sand of grain size above the limit for dune sand. For smaller grains both static and dynamic threshold wind gradients break away from this straight line relation, and both reach a minimum value together at a grain size of about 0·01 cm. The difficulty of obtaining enough uniform sand of very small size was again encountered, but there is distinct evidence that the wind required to move grains smaller than those of 0·01 cm. begins to increase again as the size is reduced. The probable cause is that the wind has now to overcome not only the friction due to the grain's weight, but also the coherence force attaching it to the other grains on the surface. Since however the same minimum occurs in water, but at a greater grain size, it is likely that aerodynamical considerations affecting the "boundary layer" conditions also enter.

Finally experiments were made using instead of sand a layer of loosely scattered Portland cement powder. The result was somewhat spectacular,

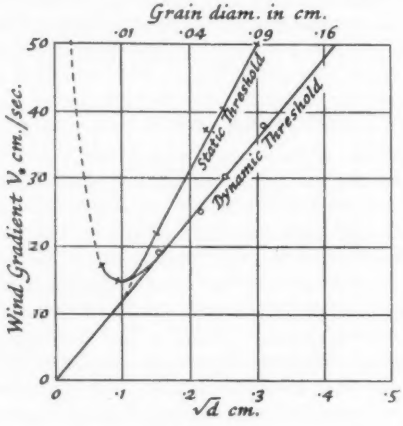


Fig. 12

for it was found impossible to set the particles in motion by the strongest wind available (equivalent to a velocity at a height of 10 cm. of about 50 miles per hour).

Hence it appears that a layer of fine particles of smaller size than 0·005 cm. once deposited by sedimentation out of the air will not be moved by the wind—unless bombarded by larger grains—and will not therefore drift into dunes. It is of interest to note that the peak diameter of loess particles is of just this magnitude.[1]

The Lymington sand lies half-way in grain size between dune sand and loess, and is therefore most easily moved by a wind. When set in motion however the effects were very different from those found with dune sand. Though the normal ripple appeared at the lowest wind speed it was only produced by a very narrow range of wind speeds. (The wave-length was only

[1] Wentworth, *Univ. Ia. Stud. Phys.*, vol. 14, No. 3 (1932); Barbour, *Geogr. J.* 86 (1935) 54–64.

0·5 to 1·2 cm.) When the wind was but slightly raised a sudden change took place, the wave-length jumping abruptly to the order of 10 cm. and the ripple shape assuming a new type unlike any wind ripple in dune sand, but in some ways resembling the stream-ripples formed under water. They are characterized in section by a symmetry of windward and lee slopes combined with a very sharp crest, and in plan by a wavy crest-line lacking in continuity. A curious feature is the occurrence of tiny markings on the lee slope resembling the normal ripples. Since the sharpness of the crest and its relatively great amplitude make it certain that a fixed eddy or vortex must exist on its lee side, it is probable that these little markings are indeed ripples, formed by the gentle reverse wind blowing backwards up the slope. The markings themselves also move backwards, and are annihilated by the advancing crest-line of the large-scale ripple. With winds of greater strength the sharp-edged ripples give place to the usual gently undulating type associated with dune sand. The fixed eddy disappears, together with the little parasitic ripples.

The experiments described in sections 7 and 8 were repeated with the Lymington sand, using the same grit as before, to see whether an increased sand-flow over the grit surface would produce an accretion of sand down-wind on the sand surface. No such accretion was formed. This is significant in providing a likely reason why this fine sand does not accumulate into dunes.

16. *Summary and conclusion*

The general mechanism of sand movement postulated in an earlier paper, whereby the grains move by bounds from impact to impact, has been verified, and the relations between the sand movement and the wind velocity distribution investigated. Since the sand movement results from repeated impacts with the surface, and since the wind velocity close to the surface is profoundly modified and controlled by the moving grains, the phenomenon seems to be a surface effect only, and does not depend primarily on the turbulence of the wind above. Hence it seems probable that conditions in a wind tunnel approximate closely to those in the open.

The rate of sand flow for a given wind gradient depends on the type of surface over which the sand passes. Under certain conditions the flow is greater over a pebbly or stony surface than over a surface of open sand. An explanation is given of how this effect leads to the accumulation of sand on an existing patch of sand at the expense of the surrounding sand scattered amongst the pebbles, etc. On this view the growth of a dune need not depend on the deformation of the wind velocity distribution by the shape of the dune as an existing obstacle in the wind's path, but merely on a change of surface texture. No doubt however the shape of the dune once formed must have a profound effect. Indeed the sand accumulation resulting from a change of surface texture is only pronounced when the sand is nearly uniform in grain size, as is the case near the crest of a longitudinal dune or on a newly formed baby barchan. It is probable that in a fully grown barchan or a whaleback, where the surface sand is not by any means uniform, continued growth depends entirely upon dune shape. But dune shape has been deliberately excluded from the scope of the paper.

A formula giving the mass displacement of sand in terms of the wind

gradient has been arrived at, and a suggested method given whereby the annual sand movement over a large tract of country, and its direction, may be computed from existing meteorological records.

Owing to a time-lag between changes in the rate of sand-flow and resulting changes in the wind velocity, fluctuations can occur in the sand movement which give rise to alternate removal and deposition. The length of such fluctuations is of the same order as the repetition distance between successive crests of a dune chain and the minimum experimental length approximates to the minimum size of dunes found in nature.

True sand ripples on the surfaces of uniform and of mixed sands have been considered together with the transition stages from true ripples to residue ridges. The wave-length of the true ripple depends on the wind gradient, and is of limited size, whereas that of the residue ridge can increase indefinitely with time. The wave-length of the true ripple appears to be identifiable with the range down-wind of the mean grain path from impact to impact.

Three distinct types of sand deposition can be defined. One gives rise to a firm densely packed deposit, probably similar in structure to wind-slab snow; another to a soft, loose deposit. These and other characteristics indicate the past history of sand deposits.

Experiments with very fine sand have shown that the threshold wind necessary to move sand grains falls with decreasing grain size to a minimum value for grains of 0·01 cm. diameter. For still smaller grains it rises again till, for a very fine powder such as Portland cement, no available experimental wind was strong enough to move the grains when the powder was spread out as a loose flat surface. It is suggested that the grain size corresponding to the minimum wind threshold marks the dividing line between sand and loess. Wind deposits of sand of mean grain size between 0·015 and 0·005 cm. do not appear to occur in nature. The behaviour of such sands in air under artificial conditions suggests that as the grain size is decreased the movement of the particles approaches more closely that of sands of larger size in a stream of water. Experiments with fine grains in air might therefore provide an easy method of studying the difficult problem of the carriage of silts of rivers.

THE CORDILLERAN SECTION OF THE CANADA–UNITED STATES BORDERLAND

STEPHEN B. JONES, University of Hawaii

FEW international boundaries are better known and few less understood than the forty-ninth parallel separating western Canada and the United States. Its striking simplicity, apparent artificiality, and long tranquillity, have made it notable, yet this very simplicity of form and function has discouraged closer study from the point of view of political geography. A few words have sufficed for a description of this line. The forty-ninth parallel was the classic example of an artificial boundary when the distinction between natural and artificial constituted most of boundary science. For its marked discordance with land forms, the Cordilleran section has been deemed arbitrary as well as artificial. Nevertheless, it bears the honourable designation "unguarded."

The forty-ninth parallel is worthy of detailed geographical study. The Cordilleran section possesses certain features which, taken together, distinguish it from all other international boundaries of the world. With insignificant exceptions, the forty-ninth parallel boundary totally antecedes settlement (other than Indian) in the border zone. It has therefore been an environmental factor persisting through all modern stages of occupation. Although superimposed squarely across the grain of western North America, few boundaries have had more peaceful histories. The discordant Cordilleran section has excelled, on the whole, the apparently more natural boundary in the Great Plains. As population crept into this already-divided land, the Cordilleran boundary, under stress at times, never gave way. Though the site is inconvenient to the verge of freakishness, mutual satisfaction with the existing line shows that its general situation must be good. The very tranquillity of the boundary gives point to the study, for here one observes nationalism reduced to its simplest terms. The cultural dissimilarities which exist between Canadians and Americans in the zone of the forty-ninth parallel are probably the least that can maintain national separation. These dissimilarities, moreover, are in large part not intrinsic but are engendered by the presence of the boundary.

The forty-ninth parallel boundary falls readily into two segments. The eastern, older portion, dating from 1818, extends from Lake of the Woods to the Continental Divide. Except for its short penetration into the Rocky Mountains, this segment crosses plains. The Gulf of Mexico–Hudson Bay height of land, the natural division between Louisiana and Rupert's Land, formed the boundary locus.[1] The forty-ninth parallel bore a rough relationship to this height of land and, moreover, passed through the Lake of the Woods, the western end of the boundary as fixed by the Treaty of 1783, though the exact relationship of the parallel to the lake was not known in 1818. The western portion of the boundary, from the Continental Divide to

[1] This term is used as intermediate between "general situation" and "site."

the Strait of Georgia, was adopted in 1846. Although having slight natural basis, this adoption extended a boundary already agreed upon and was a Solomonic decision to cut the disputed property in two.

The Cordilleran portion of the forty-ninth parallel, trending almost perpendicularly to the mountain axes, likewise intersects isohyetal and isothermal belts at high angles. Consequently, it traverses a number of well-defined and contrasting regions. Three features of the general situation are especially important: (1) The boundary, although perpendicular to the trend of the ranges, happens to fall in a mountainous zone between two plateaux. (2) The principal drainage system, the Columbia, is transected, the main stream and three major tributaries being cut by the boundary (see map). (3) The second largest drainage system, the Fraser, lies almost entirely north of the boundary.

Perhaps the most fundamental fact about any boundary is the extent of its interference with circulation. Much of the success of the forty-ninth parallel boundary may be explained by stating that mechanical transportation, utilizing a fortunate distribution of passes and harbours, has been able to facilitate east-west circulation in spite of the north-south trend of land forms.

In the early nineteenth century, the furs of the British Columbia interior moved east, through Rocky Mountain passes explored by traders of the North-West Company. In the same years, the Astorians pushed up the Columbia River, established an outpost at the Okanogan confluence, and crossed over to Kamloops on the Thompson River. The North-West Company acquired the Astor holdings and, in turn, merged with the Hudson's Bay Company. In 1824, Governor Simpson, of the combined companies, visited the Oregon country. His visit led to the re-establishment of the old Astorian route for the trade of interior British Columbia. Fort Vancouver, on the lower Columbia, became the port and headquarters. Horses were used from the Okanogan confluence to Kamloops, and beyond to a post (Alexandria) on the Fraser, above the canyons by which that river breaks through the coastal mountains.

Thus, during most of the period of joint occupancy (1818–1846), circulation in the Oregon country focussed on the Columbia River. Accordingly, the British Government, in the interests of the Hudson's Bay Company, while willing to extend the forty-ninth parallel to the Columbia, desired that river for the boundary to the sea. The swift Fraser, tempting on the map, had proved too dangerous for navigation. A complex of reasons later induced the Hudson's Bay Company, and the British Government, to accede to the extension of the forty-ninth parallel boundary from the Columbia to the sea. Polk had been elected in an outburst of chauvinism. The fur trade of the lower Columbia basin was declining. Indian troubles were increasing, with the arrival of American settlers. Ill-will existed between the settlers and the company. As early as 1843 the Hudson's Bay Company built a depot on Vancouver Island (Victoria), and in 1846 a search for new routes to the interior was begun. After a few trials, a land route from Hope (below the Fraser canyons) to Kamloops (by way of Coquihalla, Skagit, and Similkameen drainage) was established, which continued in use during the remaining years of fur trade dominance.

Gold rushes into the interior between 1858 and 1866 led to rapid improvement in routes of travel. The first great rush was to the Fraser canyons, in 1858, the miners working laboriously and dangerously up the river. Easier routes were sought, overland from the Columbia or by Harrison Lake and portages to Lillooet. By 1860, a pack trail was completed along the Fraser, through the canyons. During the rush to the Cariboo Mountains in 1860–65, this trail was superseded by the Cariboo Wagon Road. Thus, with the use of wheeled vehicles, the Fraser became the principal route to the interior on the Canadian side.

The Okanogan and Kettle valleys were prospected with some success, and spectacular rushes occurred to the East Kootenay (1863–64) and to the Big Bend of the Columbia River, north of the Selkirk Mountains (1865–66). In an effort to tap the border country from the Canadian side, a trail was built from Hope to the Kootenays, a significant but unsuccessful predecessor of the Crowsnest Railway and the Queen's Highway into the same territory. The advantages of the Fraser and Columbia routes to the Big Bend were more nearly balanced, fewer transhipments favouring the route from the United States.

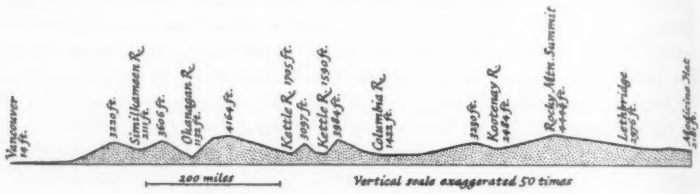
The dominance of land forms over circulation in this period affected life in many ways. Smuggling was rife, producing in 1860–61 a serious depression in the Canadian port of New Westminster, and criminals could escape easily. The southward outlook and the influx of miners gave an American tinge to the interior borderland. It is not surprising that a movement for union with the United States permeated British Columbia. The completion of the Union Pacific Railway in 1869 strengthened the southward attraction. The railway era witnessed new attempts to re-orient circulation. British Columbia exacted a pledge of a trans-Canada railway as *sine qua non* of its entry, in 1871, into the Dominion of Canada. During the fourteen years that intervened before the railway was completed, separatist movements flared up repeatedly. Completion of the Canadian Pacific, in 1885, had the desired effect of binding British Columbia to the confederation. Since half the population of the province now dwells in the terminal seaport, Vancouver, it is improbable that separatism will ever revive.

It is fortunate that the general situation of the forty-ninth parallel boundary gives good transcontinental routes to both countries. The Fraser, with deep Burrard Inlet (Vancouver harbour) near its mouth, is reached by its eastern tributary, the Thompson, over the comparatively low passes of the Canadian Rockies. On the American side, the Columbia River gorge and the low Cascade passes east of Puget Sound are easily accessible from the plateaux, while the eastern tributaries of the Columbia provide corridors far into the Rockies. Although both the Kootenay and Pend Oreille rivers join the Columbia in Canada, the southward extension of the West Kootenay valley towards Spokane makes it unnecessary for the railways to cross the boundary.

Nevertheless, the landforms of the border zone favour the approach from the United States. All but two of the major valleys drain southward, and the two that drain northward (West Kootenay and Pend Oreille) are actually more open in their southern portions. Large lakes occupy three of the British Columbia valleys. Although navigated, these lakes retard circulation towards

the north. The Great Northern Railway, constructed in 1891–93, lay uncomfortably close to what the Canadian Pacific Company considered its own domain. Numerous branches into Canada were built or purchased by the Great Northern. Meanwhile the Canadian Pacific was building and buying the lines that now comprise the Crowsnest Branch, and operating a subsidiary (the Spokane International) into eastern Washington.

The Crowsnest Branch was pieced together over a period of years, beginning with leases as early as 1890. It was not really completed until the opening of the Coquihalla cut-off between Brookmere and Hope, in 1916, and the completion of the line along Kootenay Lake, in 1930, replacing car-ferries. The curvature and profile of the branch show how highly artificial is its route. Nevertheless, with tariff assistance, this line has succeeded in diverting trade. All but a few of the Great Northern feeders in British Columbia have been abandoned. Because of its semi-political nature, the Crowsnest Branch was built entirely within Canadian territory. This requirement prevented the use of easy routes in several places; for example, the steep climb over the Rossland Mountains could have been obviated by a longer, but nearly level, route along the Columbia and Kettle rivers.



Profile of Crowsnest Branch (Canadian Pacific Railway)

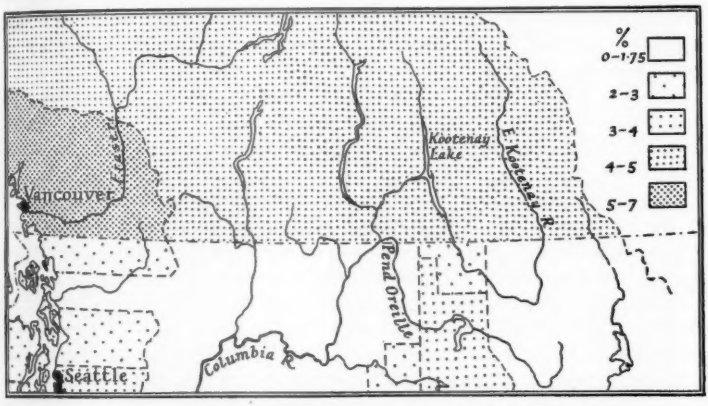
Prior to the coming of the motor-car, it might be said that railway transportation had solved the problem of the discordant forty-ninth parallel in the Cordillera, although the cost was immense. The Coquihalla cut-off cost $100,000 a mile, plus $560,000 for the Fraser River bridge at Hope. The Crowsnest Branch gave to the people of the border zone in British Columbia a fairly quick, all-year service to Vancouver or the east. The Great Northern branches drained American traffic to Spokane and Seattle. The rise of motor travel brought new problems. One witnesses the persistent British Columbian attempt to divert circulation across land forms complicated by the need for good north-south roads to attract tourists.

British Columbia faces great handicaps in highway construction. The province has an area greater than Texas, the population of Rhode Island, and the land forms of Switzerland. Whereas in the western States, federal funds pay half or all the cost of many highways, western Canada has been much less fortunate. The Dominion builds roads in national parks, but other highways are provincial, though in recent years, Dominion money has been made available for the Big Bend link of the Trans-Canada highway and for unemployment relief work elsewhere. The roads of interior British Columbia, with few exceptions, are poor. As far west as Penticton, one is invariably advised to travel to Vancouver *via* Wenatchee and Puget Sound. United

States traffic, other than tourist, avoids British Columbia roads—one of several reasons why Canadians know much more of the United States than Americans do of Canada.

Much of this north-south flow of motor travel will persist, in spite of the gradual improvement in British Columbia roads. The Queen's Highway, near the border, shares all the difficulties of the Crowsnest Branch and can never rival, for fast through travel, the routes across the Columbia Plateau. The tourist industry of British Columbia will require good roads connecting across the boundary. However, completion of three highways under construction or projected—the Trans-Canada highway around the Big Bend of the Columbia, north of the Selkirks, the road over the Monashee Mountains from Vernon to Nelson, and the projected Allison Pass highway in the Cascade Mountains—will provide short routes for much of the Canadian motor travel.

It is notable that all the attempts to re-direct circulation across land forms



Percentage of British-born in total population

have been on the part of British Columbia. There has been no need for the United States to make such efforts. The easier natural routes lie towards the south. Moreover, Canada has faced the danger, real or imagined, of becoming an economic annex to a larger concern. Throughout Canadian history, especially railway history, this factor shows itself, and nowhere better than in British Columbia. Air transport will probably show the same sequence as have other forms of transportation. First, British Columbia airways will feed into United States trans-continentals. Later an all-Canadian mail route will be established.

Had no boundary been drawn, neither the people nor the cultural landscape of the Oregon country would show any significant change near the forty-ninth parallel. Under a common legal and educational system, conducting the same basic industries in similar ways, the immigrants, whatever their origin, would have mingled to form a single culture. Such contrasts as existed in the first half of the nineteenth century between the bi-racial southern states,

with their plantation aristocracy, and the northern small farmers and bourgeoisie would probably never appear. Most of the dissimilarities between the Canadian and American portions of the Oregon country arise from the presence of the boundary.

To be sure, resemblances outnumber differences. Language is the same, except for a few words and pronunciations. Laws are so nearly alike that a traveller rarely encounters difficulty. There is similarity in the main items of merchandise. Except in history and geography, education has followed similar lines. The sequence of occupance has passed through the same stages. Save for the ever-present hedges and fences, the cultural landscape of a British Columbia town, with its rectilinear streets, false-fronted business blocks, and frame houses, differs little from that of a town in Washington.

Nevertheless, there are many dissimilarities, most of which meet without transition at the totally antecedent boundary. These differences may be divided into three classes: (1) those arising from local causes; (2) those resulting from national dissimilarities; (3) those originating in differences in immigration.

The first type shows the greatest amount of transition. For example, the importance of tourism relative to other industries grades, for obvious reasons, from low in the Columbia Plateau wheatlands to high in the British Columbia lake country.

Dissimilarities of national origin arise, in many cases, in the eastern parts of the two countries. The teaching of history in schools, for example, reflects very strongly the traditionalism of the United Empire Loyalists on the one hand, and of the Daughters of the American Revolution on the other. The retardation of British Columbia in highway construction and forest protection arises from lack of financial aid for these services from the central government. Local trade areas divide sharply at the boundary because of tariffs, in the determination of which the eastern bourgeoisie had the dominant voice. Local banks in the states contrast with branches of eastern banks in British Columbia, reflecting national policies.

The selective effect of the boundary upon immigration is demonstrated by the fact that one in four in British Columbia is British-born, and one in forty in Washington. The result is a Canadian culture not greatly different from that of the United States, but with a stronger British flavour. This fusion is typified by the common appearance, in British Columbia, of English-style hedges surrounding California-style bungalows, a combination rarely seen south of the border.

The permeability of a boundary varies greatly for different phases of life. Tourists cross the forty-ninth parallel without difficulty, and social border-crossing is easy and frequent. Investment capital flows readily across this boundary. "Ideas are light baggage," yet are probably more effectively halted by the boundary than are persons or capital. The permeability varies for different categories of ideas. Styles in clothing spread in western Canada and the north-western States almost simultaneously. Sports and games migrate more slowly. The permeability for news is almost unidirectional. Most British Columbia journals devote much space to United States affairs, while

The confluence of the Columbia and Kootenay rivers. On the left is the Kootenay and on the extreme right Arrow Lakes Valley

The West Kootenay Valley; showing the diked lands in Idaho on the left and the unreclaimed bottoms in British Columbia on the right of Boundary Creek (centre)

The Trail smelter

Doukhobor village

Old boundary monument, 1903–07

New boundary monument, 1925

the papers of a city as close to the border as Spokane ignore nearly all Canadian happenings. Patriotic prejudices are widely different.

Although immigration between the United States and Canada is comparatively free, it is hedged by imposing formalities. American law is the more formidable, and strict adherence to the letter results in considerable ill-feeling. The boundary is the only place at which one is guilty unless proved innocent.

Protective tariffs have made the boundary highly impermeable to merchandise. A large part of the display of a British Columbia store consists of American styles or brands of goods manufactured in eastern Canada. That a tariff is a tax on consumption is ordinarily concealed, but in this borderland the truth is made obvious by a comparison of prices of American goods with their equivalents on the Canadian side. Both American and Canadian manufactures are protected, but the Canadian general tariff rates are higher on most lines of merchandise, since Canadian goods are produced at higher cost for a smaller market.

As a consequence of tariffs on fruits and vegetables, these products are grown on land in British Columbia, the equivalent of which would be submarginal in the north-western States. The Creston irrigated terrace, in the West Kootenay valley, has no counterpart on the Idaho side (although American fruit also has tariff protection) for Idaho fruit-growers face the overwhelming competition of the Wenatchee, Yakima, and Hood River districts along the east flank of the Cascade Mountains.

There are few legal differences between the two countries disturbing to the ordinary person. It is noteworthy that laws of Canada and the United States tend to approach each other. Thanks to slot-machines and cash-drawers, coins and bills have grown or shrunk to the same sizes (although the cumbersome cent and the dainty silver five-cent piece still circulate in Canada).

The most noteworthy feature of these differences is the lack of a zone of transition. Obviously this situation arises in large part from the total antecedence of the boundary to settlement. Serving to perpetuate the sharp distinctions is the fact that Canadian and American ideas penetrate the other country in considerable part by radio, motion pictures, magazines, and the releases of news bureaux. The activity of these agencies is little, if any, greater near the border than at considerable distances.

Problems relating to water supply

Because of the discordance of the boundary to stream courses in the Cordilleran region, problems relating to the use and control of water-supplies promise to be numerous. Fortunately, the means of settling such disputes exists in the International Joint Commission set up by the Treaty of 1909. In addition, international stream-gauging stations in the border zone provide mutually acceptable data.

The Kootenay River has furnished the only major problem to date. The river has built a flood-plain into the southern end of Kootenay Lake, between Bonners Ferry, Idaho, and Creston, British Columbia. About 35,000 acres of this bottom land have been reclaimed and are of notable fertility. Between the outlet of Kootenay Lake, at Nelson, and the Columbia confluence, the

river drops 365 feet over a series of falls and rapids. The West Kootenay Power Company has developed 224,000 horsepower, in four plants, nine-tenths of which is transmitted to the Trail smelter. The uppermost and newest of the plants, constructed in 1931, derives its hydrostatic head from the Corra Linn dam. This dam was built with gates to raise the level of Kootenay Lake for storage, since the flow of the river varies from a midwinter low of 6,000 second-feet to an average June flood of 100,000. Raising the lake would raise the water table in the diked lands, slow up the run-off, and increase the flood danger. Because of protest by the United States Government, the power company is obliged to operate Corra Linn as a run-of-the-river plant. The United States Geological Survey periodically sends a representative to inspect the operation of the dam, and the lake level has never been raised significantly. Nevertheless, Bonners Ferry residents are prone to blame the dam for high water in the Kootenay—the familiar tendency to seek foreign causes for domestic difficulties. Actually, it is the diking itself that causes extreme high water, since the river is no longer permitted to spread over its flood-plain.

The farmers of the Canadian diked lands profit from the international character of the problem. Were all the diked lands in British Columbia, the farmers might find themselves in expensive legal controversy over the storage features of the Corra Linn dam. As it is, the activity of the United States Government on behalf of its Idaho citizens extends protection to the diked lands in Canada.

The Skagit, a south-flowing international river in the Cascade Mountains, is utilized for hydro-electricity by the city of Seattle. A projected main storage dam will create a lake 30 miles long, 7 miles of which will be in British Columbia. Although no difficulty is involved, the Canadian portion of the drainage basin being almost uninhabited, it is of interest that the city of Seattle engaged Canadian engineers and timber-cruisers for the surveys north of the border. On the basis of the data so obtained, the Canadian authorities will set a value upon the public lands affected.

The Okanogan River and its major tributary, the Similkameen (really the main stream in both volume and length), are intersected by the boundary. The water supply of the northern part of the Washington orchard district is taken from the Similkameen at Nighthawk, just south of the border. (The southern part of the district, near the cities of Omak and Okanogan, is irrigated by streams from the Okanogan Range of the Cascades, with auxiliary pumping from the Okanogan River in dry seasons.) Despite the fact that almost all of the water of the Similkameen comes from British Columbia, no trouble has arisen, because water supply exceeds irrigated land and possibly exceeds irrigable land. Under present conditions, moreover, the land in orchards exceeds the market for fruit. It is unlikely that there will be enough diversion on the British Columbia side to affect the Washington supply, for many years at least.

Problems relating to forestry

Most of the length of the Cordilleran boundary lies in forest areas. Working agreements exist between forest protection agencies in the two countries, providing for the reporting of fires across the border and for the

entrance of fire-fighters into the other country. In recent years, international forest protection in the Cordilleran borderland has been rather one-sided. In British Columbia most of the forest area is owned and controlled by the provincial government. Possessing a tremendous forest area in proportion to population, the province, although co-operating as far as possible, has lacked funds to maintain adequate protection. On the American side, in the borderland, most of the forest area is national. The federal Forest Service, reinforced in recent years by the Civilian Conservation Corps, possesses greater resources. As a result the United States fire-crews cross into British Columbia when necessary, but the reverse rarely takes place. Fortunately there have been few serious international fires in recent years. Improvement in British Columbia forest protection waits upon greater prosperity in the province or upon aid from the Dominion Government. British Columbia pays a high price in fire-swept timberland for autonomous control of natural resources.

Trail smelter case

The knottiest problem that has developed in the interior Cordilleran area arises from damage, along the Columbia River in northern Washington, by smelter fumes from Trail, British Columbia. The Trail smelter, a subsidiary of the Canadian Pacific Railway, is the largest single industrial enterprise in the interior borderland, employing three thousand men. The smelter was opened more than thirty-five years ago, attained great size during the pre-war Rossland mining boom, and is now supported almost entirely by the output of the Kimberley mines in the East Kootenay.

That smelter fumes damage crops, forests, livestock, metals, and probably health is well known. The narrow Columbia valley, acting as a conduit, carried the Trail fumes south into Washington, inflicting heavy damage as far as Northport and lesser damage as far as Marcus. The case was referred to the International Joint Commission in 1928. That damage was done was not disputed, but disagreement arose between the representatives of the smelter company and of the United States over the extent of the area of injury, the intensity of injury, whether reimbursement should be limited to actual physical damage or should cover the many secondary losses (such as the decline in property values in the area of injury), and whether the Commission should require the smelter company to install fertilizer or other plants to reduce the emission of sulphurous gases. The Commission's unanimous report, delivered in 1931, advised the payment of $350,000 for damages to 1 January, 1932, the erection of works to eliminate the sulphurous gases, and the co-operation of scientists to check the operation of these devices, but was unfavourable to the claimants of vague or remote secondary losses. The question of damage since 1 January, 1932, is now before a board of arbitration. Meanwhile, the smelter company has installed a large fertilizer plant and is planning additional fume-utilization. The international complications should therefore diminish.

Doukhobor settlement in British Columbia

The religious sectarians known as the Doukhobors (properly, The Christian Community of Universal Brotherhood) came to Canada from Southern Russia in 1898 and following years, because their simple and informal faith conflicted

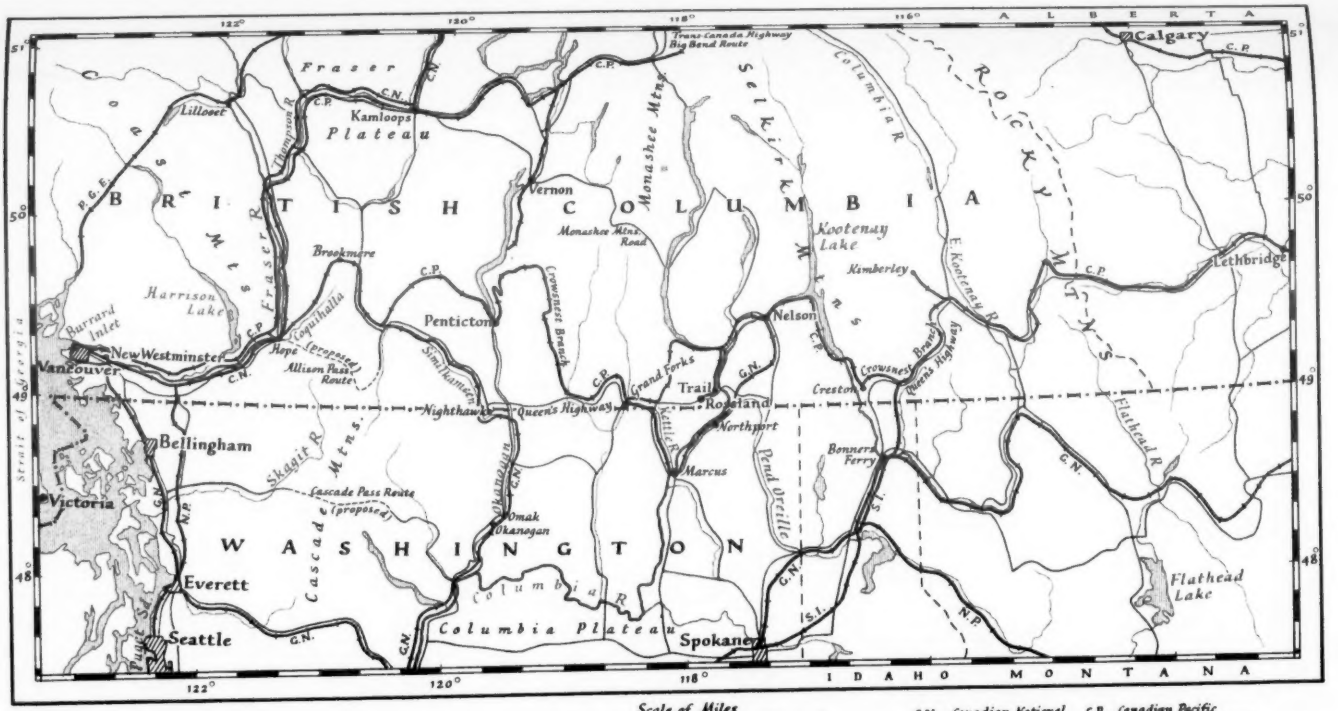
with the tenets of the Orthodox Church and because they wished to escape military service. Some entered the Prairie Provinces, but the most remarkable settlements, numbering about six thousand persons, are in valleys of the British Columbia borderland, near the Columbia–Kootenay confluence and at Grand Forks. There, the Doukhobors took up fruit-raising on irrigated terraces, setting up co-operative communities (including canneries, flour mills, saw mills, and stores) under the rule of their leader, Peter Verigin. Industrious farmers, with a communal system that greatly reduces overhead costs, the Doukhobors have survived on amounts and kinds of lands that would defeat many other peoples. Each of their compact villages holds about one hundred persons, although appearing to a stranger merely as two large houses with outbuildings. House-work is undertaken co-operatively. The farms, averaging perhaps two hundred acres of tilled land to each village, are devoted largely to fruits and vegetables, with poorer lands in pasture. The canneries provide the chief cash income. The men dress in Canadian fashion, while almost all the older women, and many of the younger, wear shawls, blouses, and short, full skirts.

Although the Doukhobors were looked upon as desirable immigrants, friction has arisen, chiefly over their not unfounded claim that religious freedom, which they had been promised, included control over education. Protest has often taken the form of burning schoolhouses and of nude parades. Forming a majority of the rural population in the valleys in which they live, the Doukhobors were able to resist forced assimilation in a manner baffling to the authorities. In recent years, much progress has been made towards solving the Doukhobor problem through the provision of a special school system, under a trustee, resident in Nelson, who has encouraged vocational subjects and nature study, gained the confidence of the Doukhobors and their present leader, the second Peter Verigin, and succeeded in establishing a chain of well-attended schools.

The Doukhobors usually refuse to register births, marriages, or deaths. It is difficult for them to emigrate to the United States, since they cannot prove either Russian or Canadian citizenship or pass the literacy test. Doukhobor villages are confined to the Canadian side of the border, stopping, in the Grand Forks area, abruptly at the boundary fence.

Nelson, B.C., and the boundary

The effect of the boundary and of tariffs upon economic geography is shown by the precocious development of Nelson, British Columbia. The city rises upon a steep hillside among rugged mountains at the outlet of Kootenay Lake. Focal location between the Columbia and West Kootenay valleys, the break in transportation at Kootenay Lake, and proximity to Trail, to mining centres, and to Doukhobor and other settlements, explain the development of a city on this site. Nelson however has more than local significance. It is the commercial capital of south-eastern British Columbia. Travelling salesmen make it their headquarters, some covering all of the province except the coast. Nelson newspapers circulate widely in the Columbia and Kootenay districts. The broadcast station at nearby Trail is the chief transmitter of south-eastern British Columbia, handling the chain programmes of the Canadian Radio Commission on a cleared channel.


122°
120°
118°
116°
ALBERTA
51°
50°
49°
48°
Trans Canada Highway
Big Bend Route
Calgary
C.P.
Fraser
C.N.
C.P.
Columbia R.
Rocky Mts.
Selkirk Mts.
Monashee Mts.
Lillooet
Thompson R.
Kamloops
Plateau
Cascade Mts.
P.G.E.
BRITISH COLUMBIA
Vernon
Monashee Mtns. Road
Kootenay Lake
Kimberley
E. Kootenay R.
Lethbridge
Brookmere
C.P.
Harrison Lake
Penticton
Crowsnest Branch
Nelson
C.P.
Crowsnest Highway
Burrard Inlet
New Westminster
Vancouver
C.P.
C.N.
Hope (proposed)
Coquihalla
Allison Pass Route
Similkameen
Grand Forks
G.N.
Trail
Rossland
Creston
Nighthawk
Queen's Highway
C.P.
Kettle R.
Northport
Flathead R.
Strait of Georgia
Bellingham
Skagit R.
Cascade Mtns.
Okanagan
C.N.
Marcus
Pend Oreille
Bonners Ferry
Victoria
G.N.
N.P.
Cascade Pass Route
(proposed)
Omak
Okanagan
S.I.
WASHINGTON
Everett
Columbia R.
Columbia Plateau
Flathead Lake
Seattle
Puget Sd.
G.N.
C.N.
Spokane
G.N.
S.I.
N.P.
IDAHO
MONTANA
Railways
Roads
Scale of Miles
20 0 20 40 60 80
C.N....Canadian National
G.N....Great Northern
P.G.E...Pacific Great Eastern
C.P...Canadian Pacific
S.I....Spokane International

The precocity of this mountain city of only six thousand population arises from the presence of the boundary. Without doubt, Spokane would be the regional headquarters were the territory undivided, assuming most of the headquarters functions that Nelson now possesses. As it is, Nelsonians look upon Spokane as the nearest big city in which to spend a week-end and Spokane contributes many tourists to the Nelson region. These non-dutiable forms of trade will increase greatly when roads between Nelson and the border are improved.

Summary and conclusions

Total antecedence is characteristic of boundaries in sparsely populated lands colonized or subjugated by outside peoples. The familiar pattern of parallels, meridians, direct lines, and rivers is observable in Canada, the United States, the Amazon Basin, Africa, and Australia. The forty-ninth parallel, more conspicuously perhaps than other boundaries of this type, has etched itself in the landscape as population has increased and settlement has matured.

Totally antecedent boundaries are moulds into which nations are cast. Sometimes unequal pressure of settlement has broken the mould, the forty-second parallel between the United States and Mexico being such a case. The forty-ninth parallel has held. Although the site, in the Cordilleran region, is inconvenient, the general situation is favourable in several ways. The boundary lies in a mountainous region between two plateaux. Good trans-continental routes and terminal harbours are available in both countries. Disadvantages of the general situation at the present stage of occupance pertain chiefly to water supply, arising principally from the division of the Columbia drainage basin. Friction from this and other causes has been largely forestalled by the creation of the International Joint Commission.

Because of the total antecedence of the boundary to settlement, immigration, circulation, economic life, and patriotism have to a great extent adapted themselves to the presence of the border. Cultural differences between the two countries, though slight, usually meet without transition at the line. Railway transportation and tariffs overcome much of the tendency of circulation and trade to follow land forms. Highway traffic is much less completely diverted. The permeability of the boundary varies greatly for different activities and phases of life.

In general, no very serious problems are apt to appear in this region, despite the discordance of the boundary to land forms. No great difficulty should be encountered in increasing the scope of present co-operative agencies when need for closer co-ordination of highway, forest, and water-supply programmes arises. To change the boundary, to avoid division of the Skagit, Kettle, Kootenay, and Flathead drainage basins, would cause more inconvenience than it would eliminate.

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RENEWED ACTIVITY OF THE GREAT GEYSER

NIELS NIELSEN

"THERE are many other wells and becks also which are sometimes flooded with water, shooting it out high into the air and covering everything near with foam." So wrote Saxo Grammaticus, the Danish historian, and it is not surprising that people in the thirteenth century knew of hot-water springs in Iceland which occasionally "shot high into the air." The early colonists would have had many and varied experiences settling in the new land, and the hot springs must have impressed them greatly. The sagas rarely speak of natural phenomena, and when they do it is always soberly and briefly; but there are many accounts dating from the Middle Ages and later times, describing hot springs and sulphur pools; indeed, the latter often figure in mediaeval fables about Iceland. The volcanoes and sulphur pools were generally regarded as the gates of Hell. In pleasant contrast to all these fancies are the real Icelandic accounts of natural events, plain and devoid of the demon fantasies of European literature. Time after time learned Icelanders sought to dispel the ridiculous ideas cherished in Europe about their country, but it was only in the eighteenth century that they succeeded.

Saxo's description of the hot springs is quite a correct one: without doubt he had his information from one who had seen them, presumably an Icelander; but we do not know if it applies to the Great Geyser itself. The first records of any hot spring in the region where the Geyser now is date from 1294, in connection with a great earthquake and an eruption of Hekla. The name "geyser" was first used in 1647 by the famous bishop of Skálholt, Brynjólfur Sveinsson, and according to that divine it erupted once every day.

The number of hot springs in present-day Iceland is almost incredible: there are several thousand at least. As a rule they are found in large groups of from ten to a hundred, all close together. They occur in almost every part of the country, from the shore and the lowlands to high up on the fells and right up to the margin of the great ice-covered mountains, the so-called *jökulls*. Actually there are grounds for the belief that there are hot springs under the ice-cap, and at certain places on the sea bottom off the Icelandic coast. Certain glacial rivers have a smell of sulphur compounds.

The activity of the hot springs varies from place to place. Large numbers of them are tepid, but many are boiling. Some boil steadily and constantly with a loud bubbling noise almost like a soup-kettle of giant dimensions, and large steam bubbles are forced up through the pipe and burst on the surface. Other hot springs have a decidedly rhythmic activity. Normally the hot water quietly wells up out of the pipe, not actually boiling; but at certain intervals boiling water and steam are ejected as if from a fountain. The most famous of all Iceland's springs of this kind is Stóri Geysir, and in former days, before the hot springs of Yellowstone and in New Zealand were known, it was unique. When those in Yellowstone Park were found and described, they were compared with the Geyser and the term "geyser" was introduced for all springs of this kind.

There is something extraordinarily attractive about the clean, pure, hot

water that rises out of the ground, by contrast with the boiling mud pools, which are probably the ugliest natural phenomenon one can see. As a rule they are rich in sulphur compounds, and they often cover a large area, comprising numbers of mud pools and steam blow-holes. The entire region is a mass of boiling sulphurous mud, and the ground is lukewarm, moist, and evil smelling. A pole pushed into it slides down as if in butter, and when it is withdrawn a little cloud of vapour issues from the hole.

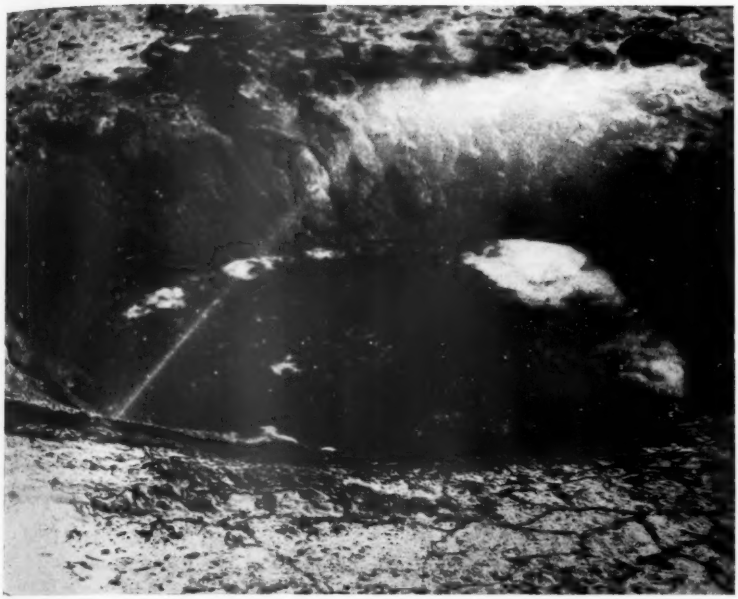
All these phenomena are associated with vulcanism, but it is very difficult to say how. It is not easy to understand how the water in the pipe reaches 100° C. or more. It cannot be the surrounding earth itself that imparts the heat, and it is at any rate partly cold ground-water that is brought up to that temperature. The Icelandic scientist Thorkell Thorkelsson considers that the heat is supplied by means of superheated steam from deeper strata.

There seems to be some connection between the activity of the hot springs, especially Stóri Geysir, and the earthquakes. The Geyser is very capricious. At times it has erupted frequently, and to great heights; at others it has been completely dormant. Round about the year 1800 it was in eruption several times a day; then it flagged, and in the years prior to 1896 there were intervals of several weeks between eruptions, though another spring in the same area erupted. Then there was a violent earthquake in 1896 which wakened the Geyser to new life. In 1897 Daniel Brunn observed fourteen eruptions in the course of twenty-four hours, the highest two reaching about 40 metres. In the next few years both frequency and height decreased. The last honest eruption was in 1907, although in 1915 the spring was seen to be very restless. After that all activity ceased; the hot water still flowed, but there was no eruption. For almost thirty years Stóri Geysir lay inactive: one of the strangest natural phenomena in the world had fallen asleep.

In recent years the hot springs have been a focus of very great attention in Iceland, and both in theory and in practice the results have been extremely interesting. The hot water is widely used for heating public buildings, dwellings, and hot-houses; swimming baths and other hot-water establishments are being built; in short, great work is being done to utilize the thermal energy of the springs, which are a valuable asset in the country's economy. From this activity Stóri Geysir benefited, for in 1935 it became possible to make it erupt again by artificial means. To understand how this happened it is necessary to consider why a quiet, hot spring suddenly begins to erupt.

The geyser consists of a vertical, cylindrical pipe with a diameter of about 2 metres and a depth of about 25 metres; through this channel the hot water streams up to the surface; the water contains a small quantity of dissolved silica, which is deposited round about the vent in the form of sinter. By this means a large cone of sinter has in the course of time been formed round the opening, and the vent now is no longer level with the ground, but at the top of this cone. At the top the pipe emerges into a basin, 18 metres wide, the rim of which is constantly being made higher and the basin itself wider.

As the 25-metre pipe has a bend at the bottom something like a water-trap on an ordinary waste-pipe, it is assumed that in the bend there is steam under fairly high pressure. The temperature at the surface of the basin is about 90° C., but at the bottom of the pipe it is about 125° C. Now if the



Stóri Geysir. Boiling water rising in the pipe five hours after an eruption

Four hours later: pipe and basin full of water

First phase of the eruption

The eruption at its height

mass of compressed steam becomes sufficiently hot, steam will pass from the chamber out through the vertical pipe; this displaces some of the water, which must run off from the surface of the basin. There follows a fall of pressure in the pipe, and as the water is now superheated, steam develops because of the boiling in the pipe, whereby more water is thrown off above and the pressure is further reduced. The consequence is a still greater development of steam, almost explosive in character, and then the spring begins to erupt. Accordingly, the factor which apparently governs the erupting of the spring is the steam pressure in the trapped part of the pipe, which must exceed the pressure of the water column in the vertical pipe with its basin.

It would thus be possible to start a dormant geyser by raising the temperature at the bottom or by reducing the pressure of the water-column

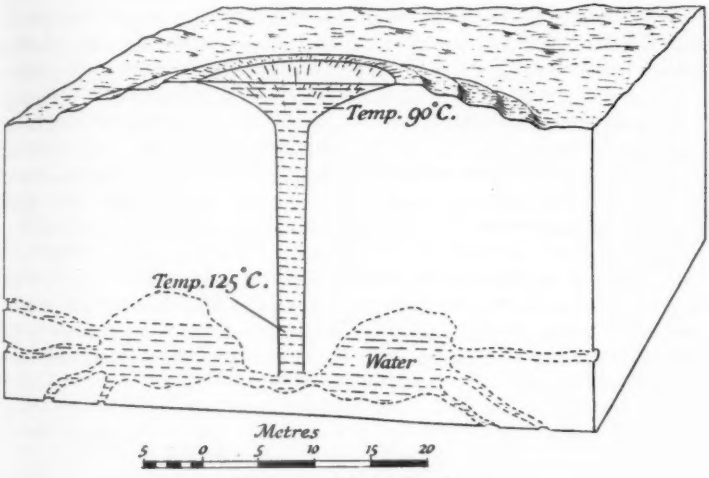


Diagram of Stóri Geysir

above: the method adopted has probably worked in both ways. For several years the lowering of the water-level in the basin by means of a powerful pump was considered. Then three young Icelanders hit upon the simple idea of digging a small ditch in the upper edge of the cone and allowing a little water to run off. By this means the pressure was reduced, and so also was the loss of heat from the surface, because its area became smaller. The experiment succeeded. The geyser has been made to erupt again by means of this tapping process, sometimes with the addition of a little soap.

In the summer of 1936 when on the IV Dano-Icelandic Expedition the writer had an opportunity of seeing Stóri Geysir in eruption. On the day we arrived there, about eleven or twelve o'clock, there had been an eruption at about 8 a.m.; the basin was now empty, and the water could be seen 3 or 4 metres down in the pipe. At intervals of a few minutes the water boiled, and the entire "kettle" filled with foam, which spurted about a metre into the air. Simultaneously the water rose rapidly in the pipe, and about 5 p.m. the

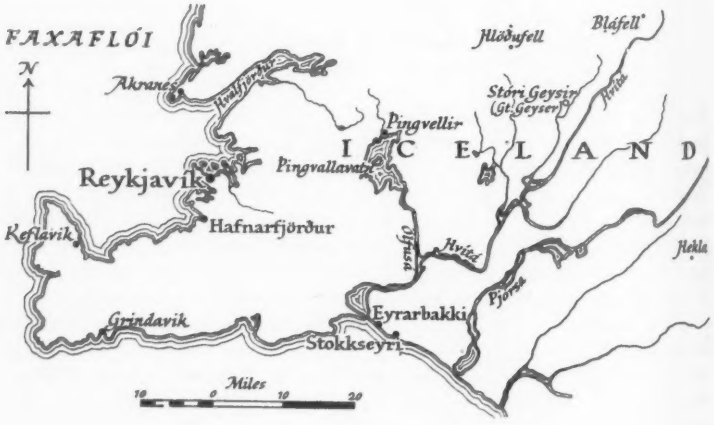
The eruption at its height

First phase of the eruption

entire pipe and basin were full, the temperature at the surface being about 90° C. An outlet was then made and a little water ran off, whereby the level was lowered about 10 centimetres; at the same time some soap was thrown into the basin. The question now was whether the process would begin. When a cold wind blows the hot surface is cooled down so much that one cannot "get the geyser up" as they say, and there was a strong wind just then.

We waited and waited, when suddenly, about 7 p.m., something happened. We were standing close by, about half a metre from the basin, when we heard a roar deep down below us. The ground trembled a little, and a wave of boiling hot water washed up towards our feet. We retreated quickly and took up a position on the outer side of the cone about 10 metres from the pipe; there also it became too lively however and we had to retire to about 20 or 30 metres away on the windward side to avoid being scalded.

The water in the basin was in an uproar. The first stage of the process resembled a continuous series of heavy dynamite explosions in the boiling basin. The water was sprayed up to the height of an ordinary five-storey house and welled down over the cone in broad, steaming surges. This magnificent sight continued for seven or eight minutes before it quietened down. And then suddenly, like a rocket, a column of boiling water stood 30 or 40 metres up in the air. The strong wind caught it and carried water and steam in a great fan towards the south. The eruption worked itself up in great gusts, higher and higher; in between the column fell to a height of 20 or 25 metres, to shoot up again to 50, 60, and even to 65 metres. The water column in this gigantic boiling fountain was two or three metres thick, white as chalk, illuminated by the setting sun against a blue evening sky studded with small white clouds. Finally, a hot column of steam poured out of the pipe with such a roar that we could not hear one another speak, even when we shouted.



THE ALLEGED PRE-COLUMBIAN DISCOVERY OF AMERICA

G. R. CRONE

SENHOR JAIME CORTESÃO'S article in the January *Journal* on the pre-Columbian discovery of America is based upon four main arguments, which may be summarized thus: (1) it was easier for the Portuguese of the fifteenth century to make trans-oceanic voyages than to coast along the shores of West Africa; (2) Portuguese official policy was to suppress all records of geographical discoveries in order to prevent them becoming generally known; (3) there is sufficient evidence to justify the conclusion that Newfoundland had been discovered by them before 1492 at the latest; (4) the Portuguese were aware of the existence of a continent to the south-west of the Cape Verde Islands before 1492, and secured an alteration in the Treaty of Tordesillas to preserve this discovery for their country.

These four arguments are all open to considerable objections, and it is suggested here that these are sufficiently weighty to require, at least for the present, a suspension of judgment on the problem of the "pre-Columbian" discovery of America.

With regard to the first argument, it is difficult to accept the statement that a trans-oceanic voyage was easier than the coasting voyages along Western Africa. In the first place, trans-oceanic voyagers would be launching out into the unknown; on the African voyages the proximity of land, both as a possible refuge and as a guide to general direction, would inspire confidence, and, what is perhaps of more importance, they were venturing along a trade-route of which they had some previous knowledge. It is not possible here to go into the details of the historical geography of Western Africa before the fifteenth century, but many of them will be found in a paper by Professor E. G. R. Taylor.[1] It is sufficient to note that there is evidence of Moorish trading activity along this coast before Portuguese expansion began, and it is admitted by the Portuguese chroniclers that Prince Henry collected information on this subject for the guidance of his captains.[2] It must also be remembered that in these voyages the Portuguese had a definite objective, known to them from the traders who had reached it overland: the gold-producing regions of the Western Sudan. The work of recent scholars has made it clear that the cartography of the fourteenth century, as portrayed, for example, in the Catalan Atlas of 1375, was based upon actual, if confused, facts of north-west African geography. There is a considerable difference between embarking upon voyages into an unknown ocean and coasting along a region, of which some knowledge already existed, towards a definite objective.

The physical conditions of the two oceanic areas are different. The southern route lay for the first part in the belt of the north-east trade winds, and off the

[1] Taylor, E. G. R.: "Pactolus, river of gold" (*Scottish G. Mag.* 44 (1928) 129–44).

[2] See Beazley, C. R., and E. Prestage: "Chronicle of the discovery of Guinea by Azurara," vol. 2 (Hakluyt Soc., 100, 1899), pp. lvi ff.

African coast the navigators were also assisted by a current which set southwards. For the outward voyage therefore the conditions were in general very favourable, and it does not appear from the narratives of Portuguese voyagers of the fifteenth century that they experienced much difficulty from storms. Diogo d'Azambuja, in 1482 for example, passed Cape Verde twelve days out of Lisbon. The Canary and Cape Verde Islands also served as convenient stages on this southern route. The conditions in the North Atlantic are less favourable. Here the prevailing winds over the greater part of the year are south-westerly, contrary winds for a voyage from Portugal to the west, and the probability of encountering storms and, in higher latitudes, fogs, is greater than in the south. So far therefore as the difficulties of navigation are concerned, the claim that it was easier to reach the North American continent than West Africa may be questioned. The length of an outward voyage by sailing ship at the end of the nineteenth century from Lisbon to Monrovia is estimated at twenty-five days; to Cape Race, Newfoundland, at thirty days. It should be noted however that the voyage from the Azores to Cape Race necessitated an eighteen-days' crossing of the open sea. It is true that the return voyage in the Atlantic area was easier, but the initial difficulties of the outward voyage had first to be overcome.[1]

The influence of the official Portuguese policy of secrecy regarding the new discoveries has been exaggerated. There is no doubt that the Portuguese would have liked to keep their discoveries secret—the point at issue is the extent to which they succeeded in doing so. In the middle of the fifteenth century foreigners were able to take part in Portuguese voyages as captains and as merchants. A Dane is said to have been killed on the West African coast in 1448; Alvise da Cà da Mosto, a Venetian, made two voyages thither in 1455 and 1456; a Genoese, Antonio de Noli, is admitted by Portuguese historians to have reached the Cape Verde Islands some time before 1460, and was among the first colonists, dying there more than thirty years later. These examples fall before the year 1481, when the penalty for interloping was death, but foreigners appear to have continued to engage in West African affairs. Columbus, another Genoese, claims to have accompanied Diogo d'Azambuja on his voyage to found the castle of El Mina in 1482, and Martin Behaim probably made a voyage to Benin in 1484.[2] It is also established that throughout this period there were foreign interlopers on the West African coast. Diogo Gomes describes how he encountered a Spanish vessel there, *circa* 1459, and three Spanish ships were destroyed as interlopers by Diogo Cão in 1483.

If the extent to which knowledge of the Portuguese discoveries spread in other countries is examined, the conclusion is equally convincing that the Portuguese policy of secrecy was not successful. Though the actual discoverer of the Cape Verde Islands is disputed, there is general agreement that the discovery is to be dated 1456–7; these islands appear on a chart drawn by Grazioso Benincasa at Venice in 1468.[3] The results of the expeditions which

[1] 'Segelhandbuch für den atlantischen Ozean.' Hrsg. von der Deutschen Seewarte. 3rd ed., 1910.

[2] Ravenstein, E. G.: 'The globe of Martin Behaim,' p. 30.

[3] British Museum, MS. 6390.

completed the discovery of the whole western coast of Africa, under Diogo Cão (1485) and Dias (1487), appear to have rapidly become known to non-Portuguese cartographers. In a collection of charts (B.M. Egerton 73) which is ascribed to 1489, there are three charts by Soligo of Venice embodying the results of Cão's voyages, which must be a copy of a Portuguese chart, perhaps that drawn by the navigator himself. There is also in the British Museum the well-known world-map of Henricus Martellus, embodying the results of Dias' voyage round the Cape of Good Hope. This too is dated 1489. Considering the importance which the Portuguese attached to the route to the Indies—this indeed forms the basis of Senhor Cortesão's argument —it is to be supposed that they would take special precautions against letting this vital information leak out: yet this they apparently failed to prevent. Whatever the reason for the mutilation and destruction of Portuguese chronicles, upon which Senhor Cortesão insists so strongly, is it entirely a coincidence that details of achievements which cannot be doubted were almost immediately in circulation in foreign countries, while claims to discoveries, advanced much later, do not appear to have reached the notice of contemporaries?

The third argument is devoted to proving a pre-Columbian discovery of Newfoundland or some portion of the North American continent. Its speculative character becomes evident if the nature of the three voyages cited by Senhor Cortesão is considered. In 1452, Diogo de Teive and Pero Vasques sought the island of the Seven Cities 150 leagues to the south-west of the Azores, and failing to find it, voyaged to the north-east with the same purpose, "till they had Cape Clear in Ireland to the west." There they found signs of land to the westwards, but did not continue their voyage. Cortesão's emendation of this text to read "north-west" instead of "north-east" is inadmissible. It can hardly be justified on the grounds of a clerical error, as that would imply that "west" had also been written in mistake for "east" with regard to the position of Cape Clear. Further, if the termination of the voyage lay off Newfoundland, the reference to Cape Clear loses much of its significance. But there are other reasons for rejecting it. If these navigators had already sought for the legendary island in the south-west, it is obvious that they had no clear idea as to its true position, and the fact that Ferdinand Columbus, writing in the following century, *after* the discovery of Newfoundland, thought it was in the west, is not a sound reason for emending "north-east" to read "north-west." Thus the result of this first voyage was merely the supposition that land existed to the north of the Azores. The second voyage, by Teles, in 1475, was less conclusive, for its results are unknown, and the third voyage, by d'Ulmo in 1486, still less so, for Senhor Cortesão admits that it cannot be affirmed that it was carried out; yet on the evidence of these three "voyages" he asks us to accept a pre-Columbian discovery of Newfoundland!

Senhor Cortesão stresses the connection between Pero Vasques and Columbus, and suggests that it was on the information obtained from the former of a land lying near Newfoundland that Columbus based his plans for a trans-oceanic voyage. If this is so, it is strange that Columbus directed his first voyage, not to the north-west of the Azores, in accordance with this information, but to the west of the Canaries.

The question of the islands which appear so plentifully in the western ocean on maps of the mediaeval and early modern ages must be regarded in relation to the general cartographical outlook of the period. Many of them have no basis in fact; some arose through the "re-discovery" of islands already recorded, or from the misinterpretation by cartographers of their documentary material. On the Soligo charts, already referred to, the Azores are depicted twice, with two sets of names. As the cartographers copied their predecessors slavishly, once an island had appeared on the map it remained there.

To connect Columbus with the earlier alleged Portuguese discoveries, Senhor Cortesão places much reliance upon an inscription on the world map in the Bibliothèque Nationale[1] attributed to Columbus, which reads: "Here is the Island of the Seven Cities, now a colony of the Portuguese, according to the Spanish mariners. People assert that we find here silver in the sand." Much of his argument depends upon the significance he attaches to these statements; yet there are difficulties in accepting his interpretation. The existence of the "Island of the Seven Cities," frequently combined with the island of "Antillia,"[2] was derived from a legend of a flight of seven bishops and their followers from Portugal before the Gothic invasion in the eighth century. This legend appears upon the globe of Martin Behaim,[3] 1492, and details are added by sixteenth-century writers, *e.g.* Galvão and Ferdinand Columbus, who refer to the presence of much gold in the sands of this island. It seems more probable therefore that, in the inscription quoted above, the "Portuguese colonists" are the legendary bishops and their followers, and that the "silver in the sand" is another version of the mineral wealth, than that the inscription is a record of actual colonization in the late fifteenth century. As to the position of the three islands, islands in this approximate area of the Atlantic are not unusual on earlier maps, for example on the Este world map of *circa* 1450.

Too much emphasis should not be placed upon the fact that discoverers, such as Cabot, claimed to identify their landfalls with the legendary "Island of the Seven Cities." Discoverers have always attempted to fit their discoveries into existing theories. A good example of this is afforded by the history of the supposed great southern continent, which for centuries dominated the speculations of cosmographers. Tierra del Fuego, Cape Circumcision of Bouvet, the Statenland of Tasman were held to be portions of this antarctic continent, until the voyages of Captain Cook in the eighteenth century demolished the theory. The identification by Cabot of Newfoundland with the "Island of the Seven Cities" cannot therefore be held to prove that earlier references to that island were based upon an actual discovery in that region. It is noteworthy that as a result of Columbus' voyages, cosmo-

[1] Reproduced by C. de la Roncière, *La carte de C. Colomb*, Paris, 1924. A. Cortesão believes its date to be after 1499 (*Cartografia e cartógrafos portugueses*, vol. 1, 241).

[2] For the history of the Antillia legend, see Kretschmer, K. : Entdeckung Amerika's, ch. 3, section 5.

[3] " . . . the above island Antillia, called Septe Citade, was inhabited by an archbishop from Porto in Portugal, with six other bishops, and other Christians, men and women, who had fled thither from Spain by ship, together with their cattle, belongings and goods. 1414 a ship from Spain got nighest it without being endangered." Ravenstein, *op. cit.*, p. 77.

graphers identified "Antillia" with the West Indian islands, far to the south of Newfoundland.

The evidence which Senhor Cortesão adduces for a pre-Columbian discovery of South America differs from that on which he bases his argument for the discovery of a portion of North America. In this instance he cannot point to any particular navigator as a presumptive discoverer, but advances an interpretation of the negotiations which led up to the Treaty of Tordesillas in 1494. These negotiations have been critically examined by Professor Vander Linden.[1] From his study it is apparent that the various Papal Bulls delimiting Spanish sovereignty in the west were issued on the initiative of the Spanish sovereigns; that the second Bull of 4 May 1493 enlarged the sphere to include "islands and continental lands (*tierras firmas*) discovered or to be discovered, not solely in the west, but also in the south, and as well in the direction of India as in all other regions"; and that this extension was probably due to the influence of Columbus. It is known that Columbus was influenced by the idea of continental lands in the south. Thus before the negotiations with Portugal were opened, Spain had endeavoured to obtain confirmation of her sovereignty over presumed continental lands in the south. This grant conflicted with earlier Bulls confirming Portuguese authority "in the Ocean Sea towards the regions lying southwards and eastwards." These claims were finally compromised; in the Treaty of Tordesillas the line of Spanish sovereignty, fixed in the Papal Bull as 100 leagues "west and south" of the Cape Verde Islands, was moved 270 leagues westwards: the problem of reconciling Spanish and Portuguese claims to the southern regions was solved by dividing it.

It is perhaps significant that Senhor Cortesão (p. 38) alters "south" to 'south-west" as the direction from the Cape Verde Islands in which John II considered there was a continent. Moreover, in the letter of the Catholic sovereigns to Columbus, referred to on p. 40, the suggestion is that there might be islands and even a continent between the Cape of Good Hope and the line proposed in the Papal Bull. The supposition that land existed in this quarter can scarcely be held to throw light upon the discovery of Brazil. It fits in however with general cosmographical ideas of the time.

It is difficult, in view of the cartographical evidence already quoted, to believe that the Spaniards did not appreciate the fact that the route by the Cape of Good Hope would ultimately lead to the Indies. The policy of Portugal in the Tordesillas negotiations appears to have been to protect this route at all costs. When news of da Gama's success reached Spain, the chagrin of the Spaniards is attributable to their realization that the Portuguese had beaten them in the race to the Indies and probably also to a growing realization that the "Indies" of Columbus were not the Indies that they had sought.

Note

Through the courtesy of Dr. R. Hennig, I have been able to study an article by him on the thesis of a secret pre-Columbian knowledge of America by the Portuguese (extract from *Historische Vierteljahrschrift*, 30 (1936), pp. 548–92).

[1] Vander Linden, H.: "Alexander VI and the demarcation of the maritime and colonial domains of Spain and Portugal, 1493–4" (*American Hist. Rev.* 22 (1916), No. 1).

His article is wider in scope than that of Senhor Cortesão, and cannot therefore be discussed in detail here. His aim being to rehabilitate Columbus as the discoverer, the point of view is hostile to Portuguese claims. He points out that there is evidence of a general interest in Western Europe about 1472 in the possibility of lands existing across the western ocean, but thinks that the attitude of the Portuguese, as evidenced in the Toscanelli correspondence, which he accepts as genuine, is proof that they had no positive knowledge at that date. He argues likewise that their procedure after 1492 is incompatible with a previous knowledge of the American continent. With regard to the Treaty of Tordesillas, he draws attention to a clause which conferred upon the Spanish monarchs the sovereignty of any islands or lands, discovered before 20 June 1494, which lay between the earlier proposed line, 250 leagues west of the Cape Verde Islands and the adopted line 370 leagues to the west.

Dr. Hennig believes that a better case can be made out for a Danish voyage of discovery, possibly with Portuguese cooperation, to Labrador and Newfoundland, *circa* 1473–4, which he considers has been unduly neglected by Portuguese protagonists. This voyage of the captains Pining and Pothorst, in which it has been suggested that the elder Cortereal took part, has been examined at great length by Sophus Larsen (see *Geogr. J.* 66 (1925) 68), and Portuguese participation has yet to be definitely established.

REVIEWS

EUROPE

A BIOGRAPHY OF MANCHESTER. By RACHEL RYAN. (Biographies of Cities. Edited by PAUL BLOOMFIELD.) *London: Methuen & Co.*, 1937. $7\frac{1}{2} \times 5$ *inches;* x+146 *pages; illustrations.* 5*s*

This book is the second of a new series edited by Paul Bloomfield and intended for the general reader and the tourist. The series has been given the very unusual title of Biographies of Cities, because the books in it are not classifiable as either local histories or guide books. It is certainly difficult to classify Mrs. Ryan's book at all. The historian would be the first to agree that it is not a local history, and the rather bewildered tourist the first to admit that it is not a guide book. But is it a "biography" of Manchester?

The first chapter gives some account of the history of the city in the past hundred and fifty years (in the course of which the repeal of the Corn Laws is wrongly ascribed to the year 1856): the remainder of the book is largely autobiographical. The author spent her childhood in a middle-class household in the southern suburb of Fallowfield, known locally then (as, indeed, it still is) as "the village." From a description of certain aspects of that childhood it is possible to gain a fairly clear impression of middle-class life in Edwardian Manchester and a much less clear impression of Manchester itself, for the background is always "a quiet suburb and much-loved garden, full of trees and flowers," which after all was the background of a distinct minority of Mancunians. The account of journeys to "Town" in train or tram reveals the extent of the urbanization of the southern districts; the contacts of the author's family with the foreign community give some indication of the part played by immigrants, especially Germans, in Manchester's cultural and commercial development; the record of an early visit to the Hallé Orchestra shows something of the influence of that unique institution.

Such descriptions, based on personal recollections, are interesting and perhaps valuable (the author hopes that her work will be "material for a future biographer of Manchester"), but to label them Manchester is misleading. There is indeed some attempt to analyse the spirit of the city and of her citizens, but to suggest that fragments of an autobiography form the "biography" of a great city such as Manchester is to put forward a claim that can hardly be substantiated. "Cities," says Mr. Bloomfield in his Introduction, "are a complex of ideas, energies, purposes, much as men are." That is true, but if it is difficult to write the biography of a great man it is many times more difficult to write the biography of a great city. "Boston," as an American once said, "is not a city, it's a state of mind." The same is largely true of Manchester, but the state of mind revealed by this book is much more that of the author than of the city which she seeks to portray.

T. S. W.

THE PRESERVATION OF OUR SCENERY. By VAUGHAN CORNISH. *Cambridge: University Press*, 1937. $8\frac{1}{2} \times 5\frac{1}{2}$ *inches;* xiv+92 *pages; illustrations.* 7*s* 6*d*

At the present time no need is more clamant than the preservation of our English scenery in open country, village and town. The Town and Country Planning Act (1932) and the Restriction of Ribbon Development Act (1935) have left action in the hands of urban and rural authorities, but how few councillors have made a special study of the aesthetics of scenery, of the pictorial

unity of architecture and nature in a rural scene, or, when rates and the schemes of local builders are on the agenda, have vision and enthusiasm enough to see the future. Urgency suggests that every member of these councils should read and digest the admirable addresses and essays in this slight, well-printed volume, which contain the essence of the matter and are an encouragement and inspiration to see the subject aright. Dr. Cornish's papers deal with national parks, trees, and buildings, the scenic amenity of Great Britain, and of the south-east of England in particular, cliff lands (a paper reprinted from this *Journal*), and the preservation of nature in England. Of the various types of scenery for which national parks and the control of their environment are proposed—mountain, moorland, woodland, and coast—it is probably the last which most imperatively demands preservation; witness the practical impossibility of now viewing an undesecrated sea, that is, from unvulgarized and unsophisticated surroundings, on the coast of West Sussex. Perhaps the most striking of the author's definite proposals is the public ownership of 500 miles of cliff best suited for the purpose. As this scheme is the vital concern not only of seaside residents but of the general public, it should be made the joint concern of the Government and of local authorities. With a breadth of 110 yards, such a pleasance would mean 40 acres to the mile, that is for 500 miles 20,000 acres, less than one-third of any of the parks proposed for the New Forest, the Lake District, or Snowdonia. The acquisition of the land at £100 per acre would mean £2,000,000. To fortify hesitating authorities, in whose vision one has little confidence, we want strong Government recognition of the real importance of such proposals. Nothing will satisfy but the setting up of a national authority and the authorization of national expenditure. These are pressing problems for authorities; they and ordinary citizens may get from these pages a very good idea of the basic conditions determining scenic amenities. S. E. W.

BEITRÄGE ZUR GEOLOGIE DER WESTLICHEN MEDITERrangebiete. Edited by HANS STILLE. No. 14. Deckenbau im Apenninbogen. By ROLF TEICHMÜLLER and HANS WILHELM QUITZOW. Pp. viii and 186. No. 15. Die Grenze von Alpen und Apennin. By ROLF TEICHMÜLLER und JANPETER SCHNEIDER. Pp. 62. No. 16. Die Faltenbögen des Apennins und ihre paläogeographische Entwicklung. By ROLF B. BEHRMANN. Pp. iv and 126. No. 17. Die variscische und alpidische Gebirgsbildung Kataloniens. By HANS ASHAUER and ROLF TEICHMÜLLER. Pp. iv and 80. (Abh. Ges. *Wissensch. Göttingen. Math.-Phys. Klasse*. III. Folge. Hefte 13, 14, 15, 16.) *Berlin: Weidmann*, 1935–6. $10 \times 6\frac{1}{2}$ *inches; illustrations and maps.* *M.*18; *M.*8; *M.*14; *M.*10

Of the four volumes under review the first three, bearing the serial numbers 14, 15, and 16, deal with the Apennines on the lines now familiar to those who have followed through the earlier numbers the work of Professor Stille's school.

Apennines and Alps are represented as parted by a narrow median zone, striking north and south in the neighbourhood of Genoa, in which divergence of movement gives a criterion for distinguishing Pennine (west-directed) and Ligurian (east-directed) structures in materials which have come from the same basin of the Alpine geosynclinal. The tectonics of the median zone itself are simple, and the nappe-structures (Ligurids), in which the materials from the same basin are found further to the east, are neither rooted in the zone nor have they slipped, or been squeezed out, from it; the whole arrangement is explicable only by large-scale underthrusting of the Foreland.

Below the Ligurids a compound series of Tuscan nappes (Toscanids and Carrarids) is exposed, whose materials were laid down originally in the same

basin as those of the Southern (Calcareous) Alps. Mainly, one imagines, on the grounds of the common ultimate origin of Ligurids and Toscanids with their Alpine equivalents, the North Apennine arc is described as "approximately a mirrored image of the West Alpine arc" (15, page 53).

To the reviewer it seems that the bilateral theory makes heavy weather here, since it is not easy to follow the course of a median zone which, apparently, crosses the lines of the different basins concerned, and the difficulty is increased when East Alpine nappes which have travelled from the east are found, on the Alpine side of the zone, in N.E. Corsica (abutting, incidentally, on what Professor Stille had already declared to be the "typical Rückland" of Corso-Sardinia).

However that be, the two sides of the mirror are sufficiently distinguished in other ways, and the history of the Apennines is not a mere reflection of the history of the Alps. It is the Toscanids, not, as one would expect on Alpine analogies, the Ligurids, which show rolling and flow structures and others characteristic of a Pennine intensity of tectonic action; and the Ligurids, unlike the Pennids, overrode all the massifs on their front, so that no central massifs are exposed in the Apennines until one passes far to the south of the Ligurid brow (which cuts the coast-line half-way between Orvieto and Tivoli).

Beyond the brow, a massif now submerged in the Tyrrhenian Sea supplied pebbles to the conglomerates of Southern Campania and the Basilicata. Still further to the south is the one central massif exposed in the whole system, the mushroom-like Calabrian Massif, which has the deceptive appearance of an active median mass from which nappes move outwards radially. But, here again, examination shows that underthrusting is responsible for the structure, and that "the Foreland has wandered on all sides under the massif" (14, page 185), which has been completely passive.

Underthrusting is in fact the *motif* of the whole story, and its persistence after the nappes had come to rest packed the North Apennine nappes and created a secondary tectonic parting, of late enough date (Pliocene) to be expressed still in the topography as a water-parting between the Po Basin and the Tyrrhenian Sea. At the same time, the gaps were filled up by new folds, and the Apennine arc was first completed, although the mountain-building movements had begun in some sectors in Laramide time, and the principal movements fall within the Lower Miocene.

The last of the four volumes, No. 17 of the series, continues the story of Catalonia, which was the first Spanish region to be treated in detail (in No. 2), and which has been touched on since then only incidentally in connection with the Eastern Pyrenees (in No. 11, for example).

Outside the Pyrenees, the topographical interest of Catalonia lies in the diversity of relief found between the sea and the barrier which the inner chain of mountains and hills opposes to the Ebro Basin. But, from the tectonic point of view, it is the Ebro Massif, at present in one of its phases of submergence, buried beneath the monotonous deposits of the basin behind the barrier, which is the centre of interest, and this volume might well be described shortly as the history of that massif from Cambrian times to the present day.

Two phases of emergence are clearly distinguished in this history, alternating with phases of subsidence which begin early in each of the two great epochs of mountain building, when the lines of the new folds largely follow the contours of the subsiding massif. While preserving throughout a broad identity, the massif varies from epoch to epoch in detail of contour. In the Variscan epoch its border ran from the mouth of the Ebro towards the Sierra del Cadí in a winding line, of whose course we get some idea by following the change of

strike from the north-west to south-east strike in the Priorato to the east to west strike beyond the Llobregat.

The outline of the post-Variscan massif shows, on the contrary, a heel at Caspe, from which a long foot (easily distinguished on the geological map by its present Tertiary cover) projected in a direction parallel to what is now the coast-line, the Mesozoic deposits of Central Catalonia being laid down on the stable shelf sloping from this part of the massif towards the Balearic Deep. Thus Catalonia was given early a Mediterranean orientation. When the Ebro Massif subsided during the Alpine epoch, and new axes of folding and faulting appeared, adapted to the heel-and-foot outline, the screening-off of Catalonia (or, more correctly, of the most characteristic part of Catalonia) from the rest of Spain was complete, and the new lines scoring the surface were Mediterranean lines, cutting across the Variscan grain.

But the deposits of Central Catalonia were protected from serious disturbance by their stable foundation on the shelf which the authors call "The Catalan Table," so that tectonic action was weakest just where the topographical and scenic interest, dependent ultimately on faulting and warping, is greatest. Where tectonic action was most vigorous, on the edges of the new Ebro Basin, the Keuper marls provided the shearing-planes for a *Stockwerk-Tektonik*, such as had arisen during the Variscan folding by the shearing-off of Devonian and Culm greywackes and limestones along the plane of older argillaceous formations. R. A.

ALBANIAN BACK-DOOR. By BERNARD NEWMAN. *London: Herbert Jenkins* (1936). $8\frac{1}{2} \times 5\frac{1}{2}$ *inches;* 316 *pages; illustrations.* 10*s* 6*d*

Most people will envy Mr. Newman not only the places to which he went but the manner of his going. His tour extended from Ljubljana, through Bosnia and the Sanjak of Novi Pazar to Lake Ohrid, then across to the coast at Durazzo, and home through north Albania and Montenegro to Dubrovnik. Save for a tour in the mountains of north Albania, the journey was accomplished on a bicycle. "George" is an essential part of the story. Mr. Newman's attitude throughout is that of a-man-on-a-bicycle. He does not set out to write a guide book, still less a political thesis. A simple narrative however is not easily maintained: there is always a tendency to insert historical excerpts culled from encyclopaedias, or set pieces of description laboriously put together long after the places were visited. Both these tendencies the author has avoided. What there is of history and politics arises out of a natural sympathy for the countries and peoples he visits, which is in itself the greatest merit in a travel book. The chapters on north Albania are amongst the most interesting. But the whole narrative is enlivened with little tales—of the influence of Greta Garbo on the women of Travnik or why the hotel proprietor at Ohrid wore a black shirt—which spring from the writer's ability to make contact with his hosts. It is in his dealings with the peoples of Yugoslavia and Albania that Mr. Newman is at his best. J. P. H. M.

ASIA

GEOLOGIE VON ASIEN. By KURT LEUCHS. Erster Band, zweiter [and completing] Teil. Zentralasien. (Geologie der Erde. Edited by ERICH KRENKEL.) *Berlin: Borntraeger,* 1937. $10\frac{1}{2} \times 7$ *inches;* viii+318 *pages; maps and profiles. M.*24.40

So much scattered research has been undertaken of late years into the geology of Asia that we must be grateful to Professor Leuchs, of Ankara, for giving us what is not purely a compilation, but contains much of his own observation.

The greater part of the immense area of Central Asia is occupied by fold-mountains of Variscan type, in which marine Palaeozoic strata are followed by non-marine Mesozoic and later formations. These indicate the long continuance of continental conditions down to the present, under which successive faunas of dicynodont reptiles, dinosaurs, and mammals have left remains still imperfectly explored.

The folds of the Alpine-Himalayan systems show a rough parallelism to the older ranges, but at several points there are divergences which enclose the Tarim basin, the smaller Ferghana and Ordos masses, and (in the northern Ust-Urt) the easternmost end of the great Fennoscandian–Russian shield. South of these enclosed areas the same geological facies continues, but marine intercalations begin to come in, and we have in the Pamirs and Tibet a transitional area, which Professor Leuchs recognizes as a shelf-area of the Tethyan ocean, before the main ocean is reached in the Himalayas.

The author has not attempted a stratigraphy of the whole region, but has given the known details of every natural area in turn. Finally comes a chapter on economic geology, and a general summary. There are numerous small maps and sections, which the reader may not always find easy to place on a general map. When meridians and parallels are given, the siting is easy, but they are sometimes omitted, and in the case of Fig. 61 the meridians are not based (as elsewhere) on Greenwich but on Pulkovo. A. M. D.

LES PAYSANS DU DELTA TONKINOIS: Étude de géographie humaine. By Pierre Gourou. (Publications de l'École Française d'Extrême-Orient, vol. XXVII.) *Paris: Les Éditions d'Art et d'Histoire*, 1936. 11×7 *inches; pp.* 666; *illustrations and maps*

Although this book, a worthy addition to the long list of valuable publications issued by the École Française, was obviously compiled as a work of reference, M. Gourou's attitude to his subject is far from being merely academic or official; and amid all his wealth of elaborately classified scientific and statistical information he never fails to display a warm human interest in the lives and affairs of the native villagers, very rare in a work of this kind. His book bears the sub-title "A study of human geography"; and he proceeds to demonstrate from innumerable angles that "the most important geographical fact in the Tongking Delta is Man."

The peculiar interest of the Tongking Delta is the contrast in population that it presents with the other great river-plains of Indo-China. The vast expanses of rice-fields in Central Siam, in the Irrawaddy Delta, and along the Lower Mekong, all produce so much more than their meagre populations need that they export rice in enormous quantities. But Tongking is hard put to it to support the $6\frac{1}{2}$ million people crowded into its area of 15,000 square kilometres, an average of 430 to the square kilometre. The author has collected population figures from hundreds of villages in the region, comparing them with those of Java, Bengal, and North China, finding that although in certain districts of Bengal the density equals that of Tongking, there is even in Bengal no area so large as the Tongking Delta wherein the population is so great.

Densely peopled though the delta is, the country has none of the characteristics associated with densely populated European regions such as Lancashire or the Ruhr. Even in Tongking's most closely peopled area, with more than 1000 to the square kilometre, it retains its rural aspect and the people remain peasants. The few towns, indeed, scarcely affect the density of population; for they account for barely 350,000 souls between them—a mere 5 per cent. of the whole.

Rice, of course, is the mainstay of the people. No other crop could be grown in sufficient quantity on low-lying land such as this, subject to ever-recurring inundation. The whole country is a network of dykes, without which the cultivation of the delta would be impossible; and there are very ancient records of the heavy penalties imposed upon persons whose negligence caused a dyke to give way. The history of Tongking is a melancholy repetition of disasters due to bursting dykes, when villages, inhabitants, fields and crops for miles were submerged under tons of mud and water. Since the last of these (in 1926) a great system of new dykes has been undertaken, which so far has proved successful.

The delta has but one tide a day. Added to the risk of flood is that of penetration by salt water to the rice-fields; and the problem of drainage is complicated by the inevitable dykes. It would appear from traces of maritime erosion at the base of inland chalk cliffs, as well as from ancient but conflicting records (p. 45) which place on the seaboard villages that now are inland, that the delta has reclaimed considerable territory from the sea; but as a set-off, the cultivated soil, which owes so much to alluvial deposits, is constantly being impoverished by the action of water, a serious problem in a region already barely able to support its population.

M. Gourou pays high tribute to the skill and tireless industry of the peasants, who labour unceasingly to gain a pitifully bare livelihood. They irrigate by hand, with various simple but effective contrivances, involving an exhausting expenditure of energy. And the author's account of their desperate efforts to fertilize their land raises an unsavoury subject to the realm of high endeavour. Children collect in baskets every morsel of manure from the cemeteries and dykes (the only pasturage); human excrements are carefully conserved and carried to the fields; and the same material is transported to a radius of 20 miles from the towns by processions of women, with vessels slung from bamboo poles across the shoulders.

The unit of Tongkingese life is the village, and the author devotes many pages to its customs. Every village is surrounded by a tall bamboo hedge, as beautiful as it is an effective defence against marauders, and has gateways of brick, with doors closed and guarded at night. In any time of rebellion an offending village is made to cut down its hedge as a mark of shame, leaving it "like a person stripped naked and exposed to the derision of the crowd." Each village has a curious communal solidarity, and the inhabitants make common cause against those of another. It is a community in which public opinion absolutely controls the life of the individual: an affronted wife will charge her erring spouse before the village headmen; a villager whose house has been robbed invites the headmen to hold an inquiry on the premises, where he must provide a feast of dog, for "a dog cutlet washed down with a cup of rice wine is considered a great delicacy." A dog convicted of biting a man is executed, and eaten, not by the person it bit, but by the village authorities. Every house has its pig-pen, for the construction of which planks from disinterred coffins (from which the bones have been removed for final burial) are in demand, being conducive to the health and rapid growth of the pig. The people are so poor that they hunt rats for food, and the grand annual rat hunt after the rice harvest is an important event.

The author is at pains to point out, with the aid of many drawings and photographs, that poor though the Tongkingese peasants are, their houses are not the haphazard dwellings of a primitive people, but are erected on definite, symmetrical, and elaborate plans of great religious significance; and it is the first concern of a man, who has saved sufficient money, to erect a house which will suitably shelter the tablets of his ancestors.

M. Gourou describes a number of the native crafts, among them cotton-wool padding for winter garments (made from locally grown cotton), silk, dyes, joss-sticks, netting, bricks, tiles, and paper, the last used chiefly for fans and the model boats, animals, garments, money, and other objects burnt at funerals and as offerings to the Spirits, various villages specializing in each craft. The author discusses the possibilities of exporting these products as a means to relieve the people's poverty (quoting as example the Javanese hat trade), and a better adjustment between Tongking and its neighbours; the quantities of fish-nets now imported from China by Cambodia and Cochin-China, for instance, could well be supplied by Tongking.

M. Gourou rightly deprecates any sort of "progress" which would give the Tongkingese peasants the "blessings" of modern machinery to ameliorate their present laborious lives. By robbing them of their work with its tiny recompense it would leave them (he says) "nothing to do but to die discreetly." The book is illustrated with magnificent photographs. H. W. P.

ESQUISSE D'UNE ÉTUDE DE L'HABITATION ANNAMITE DANS l'Annam septentrional et central . . . By PIERRE GOUROU. (Publications de l'École Française d'Extrême-Orient, vol. XXVIII.) *Paris: Les Éditions d'Art et d'Histoire*, 1936. 11 × 7 *inches;* 80 *pages; illustrations and maps*

This study of the domestic architecture of Annam is a sequel to the section on Tongkingese building included in the foregoing work. The author traces the regional differences in style, southwards from the delta, as the Annamite people, during nine hundred years, pushed their conquering way down the 2000-kilometre-long ribbon of territory, where however the defeated Chams still continued to influence the architectural style of their former kingdom. As in Tongking, says M. Gourou, house building in Annam is so bound up with law and custom and religious beliefs that full knowledge of it would give the key to the ancient, unknown Annamite civilization, "whose roots are deep hidden under a thick coat of Chinese varnish." The author emphasizes that his treatment of the subject is anything but exhaustive, long and detailed research in each separate region being required. He urges that such researches be undertaken before the old-style houses, built by craftsmen according to a thousand ancient rites, disappear and give place to the characterless, quasi-European, modern erections of Cochin China. This volume also is rich in admirable photographs. H. W. P.

THE WILDERNESS OF ZIN. By C. LEONARD WOOLLEY and T. E. LAWRENCE; with a chapter on the Greek inscriptions, by M. N. TOD. *London: Jonathan Cape*, 1936 (first published by the Palestine Exploration Fund, 1915). 10 × 7½ *inches;* 166 *pages; illustrations and maps.* 18*s*

This monograph upon the physical conditions and archaeology of the region between the Dead Sea and Akaba, originally published as the Annual of the Palestine Exploration Fund for 1915, and well known to those interested in its subject-matter, does not require lengthy notice here. In its present form it is intended for the larger body of general readers, who will be attracted by the reputations won later by its authors. The general reader will find in it a lucid description of the geography of an area still little known written in an attractive style not usually associated with works of this kind. It provides an outstanding example of how exterior historical influences can impart to a region an importance which would not be deduced from the intrinsic conditions offered for human settlement. During the Byzantine period it possessed special importance as a frontier tract, and appealed to the religious-minded as a refuge from the

world; consequently the archaeological material is concerned almost exclusively with the remains of Byzantine settlements and ecclesiastical monuments. The thoroughness with which the authors carried out their task in a short visit is vouched for by Sir Frederick Kenyon. After the lapse of more than twenty years the book remains as an authority in its particular field. Forty pages of plates, reproduced from the original edition, give a very complete conspectus of the area and its historical monuments. G. R. C.

AFRICA

DESERT ENCOUNTER: An adventurous journey through Italian Africa. By KNUD HOLMBOE. Translated from the Danish (first published in Copenhagen, 1931) by HELGA HOLBEK. *London: George G. Harrap & Co.*, 1936. 9×5½ *inches; 282 pages; illustrations and route-maps.* 9*s*

Knud Holmboe undertook an arduous journey from Spanish Morocco eastward, hoping to reach Egypt. He used a single car, which appears to have been decrepit from the outset, and his equipment was inadequate. His best assets were his knowledge of Arabic, his Moslem faith, his determination and courage. It is astonishing that he got as far as he did, and at times his chances of survival were slight. He was perpetually encountering trouble. The journey might have been done more effectively, with fewer adventures, and less trouble to others, if Holmboe had acquired more precise knowledge of his route, of its difficulties, and of means of overcoming them. Those who like to read of an adventurous journey will get their money's worth.

His account of native affairs along the coast should be read carefully. He entered an area of bitter guerilla warfare of which very little is generally known in this country and he saw much that aroused his burning resentment: he presents a picture which is not seen, for example, by readers of a recent article in the *Geographical Magazine*. It is to be hoped that the hospitality, which he was so careful to respect at the time, has not since been visited on his hosts. The views of Italian officers and the alleged conversations with natives are published *verbatim* and names are freely given. Some of their views constitute severe criticism of the higher authorities, and publication may help neither the less fortunate of the Arabs nor the well-disposed officers of whose far-seeing efforts Italians will be proud. Publishers and authors should set an example by considering the fates of those whom they are jeopardizing by feckless predilection for "copy."

The journey was a remarkable performance, conducted with great courage and endurance, with a foreknowledge that the difficulties would be almost insuperable. The book states bluntly the author's observations of what has been taking place in parts of North Africa. It would do good for those who live in security in Europe to realize some of Italy's colonial problems.

Holmboe paid dearly for his devotion to the Arabs. The Italians imprisoned him—he had in fact been a considerable nuisance to them—and at a later date Arabs killed him when he, a Muslim, attempted the pilgrimage to Mecca. They killed a champion of their cause who, through the international press, might have done them great service. K. S. S.

THE BORNU SAHARA AND SUDAN. By Sir RICHMOND PALMER. *London: John Murray*, 1936. 11½×9 *inches;* viii+296 *pages; illustrations and maps.* 42*s*

Sir Richmond Palmer, at present Governor of Cyprus, has put into this volume the results of many years' researches into the history of the Kanuri or Baribari

people of Bornu, and neighbouring tribes in the British Protectorate of Njgeria, and in the French Territories to the north and east. Bornu history has a respectable antiquity. We have here translations from the Arabic of twenty Grants (Mahrams), of historical interest, issued by the Rulers (Mais) of Kanem and Bornu over a period of nearly eight hundred years. The earliest dated grant is A.H. 580 (A.D. 1184), but there are two earlier ones, conjecturally dated A.D. 1086. In the list of the Maghumi Rulers we are dealing with still more ancient history. There are no fewer than sixty-eight of these rulers. The conjectural date for the third of them is A.D. 600, and the last four of the line, which ended in 1846, were already overshadowed by the Kuburi sheikhs, who succeeded them as rulers of Bornu down to the present day. Of great interest also are three documents concerning the Tuareg Sultans who have ruled Aïr or Asben since A.D. 1406.

Valuable as these documents are, they necessarily form but fragmentary material for tracing the continuous history and movements of peoples. In his explanatory notes the author relies much upon the mediaeval Arabic writers, Ya'aqubi, El Bekri, Idrisi, Ibn Khaldun, Maqrisi, and Leo Africanus. But these six authors, whose information about the Sudan is frequently obscure, are spread over a period of seven centuries. It is not surprising therefore if one gains the impression that the author is spinning large webs of conjecture on the basis of ancient names of places and peoples, and tracing name resemblances from century to century in spite of the changes caused by transmission from one language to another.

The author believes that the term "Bornu" or "Barnu," and "Baribari" or "Barbar," to be a people name, and connects it with the Greek *barbaroi* and the Latin *vir*. He considers that the Baribari people have many connections and a kindred origin with the Tuareg tribes. Although he believes that the eastern half of the Sudan, *i.e.* east of Tibesti, had large Christian elements up to the fourteenth century, he rejects the suggestion that the cruciform ornaments and patterns used by the Tuareg are of Christian origin. He derives the Cross in this connection from the much older triangular decoration used by the Blemye people of the Eastern Sudan, and the triangle itself from the oxhead with pointed horns. The author appears to regard the Blemyes as nomad Barbar stock, perhaps akin to the Tuareg, and apropos of Pliny's legend that the Blemyes had no heads, their mouths and eyes being in their chests, he remarks that this might easily be the impression given to a frightened traveller by the Veiled Tuareg of to-day.

As to the origins of the Tuareg and Baribari, the author believes that in the reign of Septimius Severus (A.D. 193–211) there was a large influx of Syrian or Palestinian people into North Africa (hence the name Tura applied to white people in many parts of the Sudan); that in the two centuries of disturbances following this influx, *i.e.* A.D. 200–400, is to be set the appearance of the Tuareg and the camel as new factors in North Africa; but that the original home of the Tuareg is to be found in the Rif of Abyssinia and the north-east horn of Africa. He quotes Procopius concerning the dealings of the Byzantines, Diocletian, Justinian, and Belisarius with Aksum (the Agisumba of Julius Maternus), and with the Blemyes and the Nobatae of the eastern Sudan.

Not until the sixteenth century do we get clear historical narratives, and we can then picture the general condition of the Sudanese peoples as very similar to what Barth described in 1850 and the British Protectorate found in 1900. The author quotes extensively from the Infaku'l Maisuri of Sultan Bello of Sokoto, a translation of which was printed by the Emir of Kano's Press in 1928. Bello, writing about 1820, quotes from sixteenth-century authors

Ahmed Baba and the Tarikh es Sudan, and we can see that by this time the Tuareğ tribes were established in Aïr and the southern fringe of Sahara. The Dagira (Daura) and Gobir peoples, dislodged by the Tuareg, have long been settled in their present homes, while the Rulers of Bornu are warring with the Askia Sultans of Songhai, with the Tuareg of Aïr, or with Kanta of Kebbi.

The Infaku'l Maisuri records shortly the Fulani traditions of their own origin and also that of the Baribari, the Tuareg of Aïr, and other Sudanese peoples, but its main value is the contemporary account of the jihad of Shehu dan Fodio and the partial Fulani conquest of Bornu. The author considers that the vivid controversial letters exchanged between the Sokoto leaders and Sheikh el Kanemi of Bornu present a fairly complete résumé of the origin of the Fulani conquest of Hausaland.

An interesting early sidelight on the Sokoto-Bornu controversy is thrown by Bornu Mahram M., dated A.D. 1694. This is a grant of tax exemption to the Fulani in Bornu, whose leader's title is Gabidama (*i.e.* owner of the land of Gabi or Kebbi). One of the witnesses to the document is Ayesha, daughter of the Mai, and she has the title of Sokotoma. The town of Sokoto (Sakwato) was not founded before 1808, but the name was evidently in ancient use for that locality. It is interesting also to notice that the Mai of Bornu uses the titles of "Amir ul Muminin" and "Khalifa of this land," just as Shehu dan Fodio did over a century later at Sokoto. E. J. A.

NORTH AMERICA

OUR NATURAL RESOURCES AND THEIR CONSERVATION. Edited by A. E. PARKINS and J. R. WHITAKER. *New York: John Wiley & Sons . . . London: Chapman & Hall*, 1936. 9×6 *inches;* xii+650 *pages; illustrations and maps.* 25*s*

For little more than a century the American peoples, in their great westward expansion beyond Appalachia, have been crashing their way through the forests, ploughing up the grasslands and overstocking the great ranch lands beyond, taking an irreplaceable toll of their timber, soil, and mineral resources. Europe, for the most part, sowed her wild oats much earlier; thus her indiscretions were not associated with modern wholesale means of exploitation, nor could there be the record of scientific observers. In America, the geologist, the forester, and the agriculturist have for some decades been making their reasoned protests, and it is nearly thirty years since Van Hise issued his now classical work on 'The Conservation of natural resources in the United States,' the real forerunner of the work under review. Since his day the evidence has accumulated, and the protests assumed a weightier significance; but it has taken the depression of recent years to rouse a pioneer nation from its *laissez faire* attitude. Under the present régime a positive spate of sociological research, and of economic planning, has focussed attention anew upon the fundamental importance of natural resources.

Commissions on Power Resources, Soil Erosion, and Transport have recently reported; and in 1934 the Natural Resources Board issued a comprehensive account. Thus the contributors to the present work, though their names are a sufficient guarantee of cognizance of the matters with which they deal, have the additional advantage that much pertinent material has recently been summarized and brought up to date. To each of the several authors is allotted one subject: Soils, The Conservation of Semi-arid Lands, Water Power, and so on; and in each case the treatment is not confined to a summary

of the possibilities of conservation, but is prefaced by a non-technical account of the resource itself, and of its exploitation up to the present.

It would be quite impossible, in the space available, to review each of the twenty-two sections separately. They reveal varying degrees of penetration, and some of the subjects have been dealt with by the same authors elsewhere. In particular, this is so in the case of the very important contribution of O. E. Baker on "The Agricultural Prospect"; but his material certainly deserves the attention of the wider public who will read this book. His analysis of the effect of changing population, changing dietaries, and of farm mechanization (especially in relation to the release of land formerly devoted to the production of feed for work animals) is of the greatest interest.

H. H. Bennett, of the soil conservation service, is in a position to report nearly 50 million acres of land, outside the arid western region, as "essentially destroyed by wind or water erosion, so far as general use for crop production is concerned." From a further 87 million acres the top soil has been removed.

That the reader may the better understand this chapter, it is properly prefaced by a quite excellent summary of the soils of the United States by Louis A. S. Wolfganger. Here is a subject notoriously full of pitfalls for the beginner, and requiring expert skill in its presentation. J. Russell Smith, in his chapter on "Tree Crops," has an interesting preliminary aside on the influence of the thunderstorm, the clean tilled crop (corn, cotton, and tobacco), and, in the south, the inferior turf, as important agents in the relatively greater erosion in America as compared with that known in Europe. But the U.S.A. has some soils for which there is no equivalent in Western Europe.

The influence of forest cover in the protection of watersheds is properly emphasized, and without that over-statement characteristic of writers on forestry of some decades ago. Part V of the book is a sequence of chapters on water supply, power, waterways, and flood control. Here one might quarrel a little with the order; for the whole of this part should have been prefaced with a brief account of the regional relationships between precipitation, run-off, transpiration, and ground water. The book is professedly not for the expert; nevertheless these fundamentals have received less explanatory treatment than have those which underlie the other subjects treated.

A. E. Parkins gives a refreshingly frank account of public expenditure on waterways, and of the apparent wastefulness of much of the effort. That farmers should have their goods transported thousands of miles for approximately nothing; that water transport is inevitably, at all times, and in all places, cheaper than land transport; that water power being a natural resource, costs nothing to develop or to distribute; these seem almost to be popular tenets of a great democracy, and not in America only.

There is a sensible chapter on the preservation of national parks and the provision of recreational spaces, objects which we, in our more crowded country, would do well to consider.

Rivers, forests, soils, power resources and natural resources generally, have no relation to state boundaries; and their exploitation, as their conservation, should be planned on the basis of more natural divisions. The matter is dealt with by G. T. Renner in the final chapter on regional planning, the reading of which recalls to the reviewer the fact that as early as 1694 a Collector of the King's Customs suggested a more reasonable division of the land east of Appalachia than that determined by the boundaries of the thirteen colonies.

Throughout the book as a whole, remedial measures are as clearly indicated as are the modes of recent and of past exploitation; but there is little discussion of the economics of conservation. These are difficult to estimate; but although

not all the measures can be taken, it is important that efforts should be directed to those projects which are concerned with the solution of the most critical problems, and that results should have a reasonable relation to costs.

This book deserves a very wide circulation in the colleges and schools of the United States. Students of the geography of North America will find it an illuminating sequel to their text-book study of the continent. LL. R. J.

ALONE ACROSS THE TOP OF THE WORLD. By DAVID IRWIN. *London: Robert Hale and Co.*, 1936 [1937]. 9×5½ *inches; 254 pages; illustrations and route-map.* 10*s* 6*d*

This is an account of a single-handed journey across the greater part of Arctic Canada, a journey of about 2000 miles. The author had himself put ashore in the autumn by a trader, west of the Alaskan boundary, and finished up two years later near Baker Lake. The official purposes of the journey were prospecting and a search for remains of the Franklin Expedition, neither of which was successful, but Mr. Irwin makes no effort to hide his real reason, which was simply to see if he could do it. He joined up first with the great Alaskan reindeer herd, which was then almost at the beginning of its trek to the Mackenzie River, but had to leave it because his efficiency made the Eskimo herders jealous, and thereafter he travelled alone, spending the first winter with a storekeeper at Barter Island, and the second mining in Cameron Bay. He finished up somewhere north of Baker Lake, having lost his sledge through the sea-ice, and nearly starved to death before being found by two Eskimo.

To come through this was a very fine achievement, but this account, which suffers perhaps from being written up too much, leaves one wondering why the journey was made, for the book is mainly a record of hardship. The author seems to have found the Arctic attractive only because it was harsh and almost unendurable, and of the many pleasures of polar travel he seems to have experienced only those of accomplishment and of cessation from discomfort. One may sum it up as a direct contradiction to the 'Friendly Arctic.' There is only a rough map in the end papers, and it is in no sense a topographical record, but there are several interesting notes on the hunting methods and customs of the Canadian Eskimo. J. W. W.

POTLATCH AND TOTEM, and the recollections of an Indian agent. By W. M. HALLIDAY. *London: J. M. Dent & Sons*, 1935. 8½×5½ *inches;* xvi +240 *pages; illustrations.* 15*s*

Those who do not know of the Potlatch, of the fierce rivalry, the lifelong jealousy, and the pride of those who sought to outvie all in generosity, and who do not realize how important a person economically a chief may be in other cultures, will welcome this clear and straightforward account of the Potlatch and its ceremonial, based on a long and intimate and sympathetic knowledge of the Kwakiutlin British Columbia. Perhaps it was time that the custom was ended, although within limits it did undoubtedly promote production. To destroy a custom so deeply rooted as Potlatch, without providing a substitute, would bring down other, perhaps praiseworthy, elements in the culture. Totem magnificence was an incentive to artistic development; it was also a bond of union, a symbol of pride, an emblem which gathered round it much of the lore of the past. Simple narratives such as this often present to us features of great interest, and though not scientific in a rigid sense, provide raw material in which there is much human interest. The strength of the cultural ideas which underlie the Potlatch is manifest also in the art which their brand of totemism has fostered. T. C. H.

CENTRAL AND SOUTH AMERICA

BATTLEFIELD OF THE GODS: Aspects of Mexican history, art, and exploration. By PÁL KELEMEN. *London: George Allen and Unwin*, 1937. $8\frac{1}{4} \times 5\frac{1}{2}$ *inches;* 212 *pages; illustrations.* 10s 6d

Mr. Kelemen's "battlefield" lies in the regions of what is now Mexico, which include certain Maya and Aztec sites, and which are more widely differentiated than the author explains; the conflict is that between native religions of Maya and Nahuatl peoples and the Christianity introduced by conquering Spaniards in the early sixteenth century. The survey of the remains of pre-Columbian civilizations made by Mr. Kelemen was by no means wide enough to justify his resounding title; but the book is well, and sometimes brilliantly, written, and in the course of the first hundred pages displays a sound appreciation of the facts of Maya origins, whose intricacies have tripped up so many easy theorists in the past.

The author travelled, after visiting Merida and the two nearer Maya sites, to Mexico City, paying the usual tribute of newcomers to the places of interest in and near the capital. He seems however to have been more attracted to Spanish Colonial architecture and decoration than to ancient Nahuatl remains, and to have been diverted by modern Mexican art and entertainment. Throughout the volume many pages are filled with long quotations from the works of previous writers on Yucatan and Mexico, and one can but wish that Mr. Kelemen had condensed this evidence and employed his gifts to the formation of a better coordinated volume, relating Maya and Aztec questions to the history of Mexico. Mr. Kelemen is no geographer; but he is undoubtedly a keen observer and possesses an attractive literary style. The photographs illustrating the book are adequate to the text, although not always of first quality. There is no map; index sufficient. L. E. J.

SAILING SOUTH AMERICAN SKIES. By JAMES SAXON CHILDERS. *London: Arthur Barker*, 1937. $8 \times 5\frac{1}{2}$ *inches;* 284 *pages; sketch-map.* 7s 6d

This is a lively and perhaps rather ostentatiously naïve account of flights made by an American journalist, starting from Texas, to Mexico City, certain capitals of Central America, the Panama Canal Zone, and down the West Coast of South America, stopping at Buenaventura (Colombia), Guayaquil, Lima, Santiago de Chile, and over the Andes to Buenos Aires. From here Mr. Childers flew to Montevideo, Rio de Janeiro, Belem do Pará, and up the Amazon to Manáos. There was no attempt to get off the beaten track and, flying from capital to capital at frequently considerable heights, the author found little of the genuine atmosphere of Latin America that road travellers cherish. He found Mexico and Central America "dull" and "thoroughly dull," and Colombia the same. He did not of course know much of them. His interest was first awakened in Ecuador, when he took a rail and car journey to Quito; and the fact that he was now more or less on his feet and could see the country and the people, and therefore felt the excitement of travel, should have taught him what was wrong with his previous experiences.

A brisk style, at its best when the author relates personal impressions and especially air sensations, as when he crossed the Andes, renders the book extremely readable; its merits as a contribution to knowledge of South America are less conspicuous. It is difficult to understand his ready acceptance of such stories as the death of Sandino, and of the fire-eating American filibusters who, he thinks, dominated Central America not so long ago. One of these gentry had been, Mr. Childers gravely reports, "Commander-in-Chief of the Colom-

bian Army and Navy"; another was the late "General" Lee Christmas, well known to the present reviewer in his later life as a mild and almost illiterate person, keeping a fiftieth-rate hotel in Puerto Cortez, and grateful to receive a small pension from the Government he is supposed to have terrorized. Similar credibility marks the author's account of the Jivaro head-hunters; and is probably responsible for his denunciation of "some Englishmen" who pretended to be "just looking round" in North Brazil, "stole" rubber seedlings which they "cut out" from the forest, grew in a "London hot-house" and took to Ceylon, and so "strangled Manáos." One wonders if Mr. Childers thinks it was equally wicked for coffee to be grown in South Brazil. Despite these weaknesses, which any good journalist could have avoided by examining his subjects, the book makes cheerful reading. It does prove conclusively however that a knowledge of South America is not acquired from the air. L. E. J.

AUSTRALASIA AND PACIFIC

THE RED CENTRE: Man and beast in the heart of Australia. By H. H. FINLAYSON. *Sydney, Australia: Angus and Robertson (London: Australian Book Co.)*, 1936. (Second Edition.) $9 \times 6\frac{1}{2}$ *inches; 154 pages; illustrations and map. 7s 6d*

This book is an interesting quasi-scientific narrative of extensive travel by the author in the little-known south-west region of Central Australia, which is popularly, though erroneously, supposed to be "desert country." In simple language, yet with a precise correlation of facts, Mr. Finlayson, who is Honorary Curator of Mammals to the South Australian Museum, deals descriptively with the varied physical features and the comparatively wide range of animal and vegetable life still to be found largely in a primordial condition in Central Australia. Systematically and authoritatively, the author interests the reader in the ranges, the tracts of country surrounding them, the tors, the animal and vegetable life and the Australian "blackfellow"—a widely used appellation for the Australian aboriginal. Throughout the book one finds many unusual, though welcome, flashes of retrospection. For example, Mr. Finlayson says "the feeling is stirred by many parts of the Centre," and that "it needs no foreknowledge of its geographical history to see and to feel the influence of the old-time seas in shaping the contours of the lower lands." Three chapters are given over to describing the geographical features in detail. A similar number are devoted to animal life, and it is here that one learns of the author's interesting search for and rediscovery of the plain-rat-kangaroo (Caloprymnus campestris), an amazing little animal about the size of a rabbit, built like a kangaroo with long spindly hind legs, tiny forelegs folded tight on its chest, and a tail half as long as the body.

The three chapters relating to the Australian aboriginal constitute an excellent anthropological study, and Mr. Finlayson has contrived, by the scientific clarity of his writing, to present a pen-picture of these nomadic people which will appeal in no less degree to the scientist than to the layman. To these people, whom the author is at pains to defend from the allegation of stupidity, is ascribed good physique and a complexity of character, but no great superiority, if any, to the white man in enduring heat, thirst, and hunger while on trek. There appears no evidence that, among the Australian aboriginal, there exist those implacable hatreds and endless blood feuds which have convulsed other primitive peoples; or of deliberate cruelties and lusting delight in another's pain which, Mr. Finlayson says, "in the American peoples, served to remind one that man is part fiend as well as beast." In the matter of food these people

appear to have prodigious capacities—the author credits two men with eating a large kangaroo, at least fifty pounds of meat, at one sitting, which lasted from noon till dusk! Their ability to ingest enormous quantities of food is by no means their only gastronomic feat, for it is recorded that they can imbibe literally gallons of water in a steady process of drinking. One authentic instance is quoted of a man who, at the end of a long and hot day's work, drank seventeen "jampeters" of water, which, when measured, worked out at something over three gallons. Transport is dealt with at some length in three chapters of the book, and here pride of place falls to that beast of burden—the camel, whose supposed aesthetic and temperamental shortcomings find a ready champion in Mr. Finlayson. The book ends appropriately with a chapter on "The White Man," in the penultimate paragraph of which the author, perhaps unconsciously, gives the somewhat wistful, but understandable, impression of hankering after another of "those lonely tilts with fortune" by which he describes the work of exploration in Central Australia. Perhaps one day in the near future the scientific world may again hear of him setting out astride a beast of Asia to the accompaniment of "the hiss of cushioned feet in the hot sand." Then will hope run high that Mr. Finlayson may be inspired again to give the world the benefit of his scientific observations.

'The Red Centre' is well produced and printed on good paper, and contains fifty-two full-page plates which illustrate the letter-press. Not only have the photographs been skilfully taken but the subjects have been selected with scientific and artistic care. The author has included, as an appendix to his narrative, an excellent map of Central Australia, by which his travelling routes can be followed easily. O. C. W. F.

ADVENTURING IN CORAL SEAS. By ALBERT F. ELLIS. *Sydney, Australia: Angus and Robertson* (*London: Australian Book Co.*), 1936. 8×5 *inches;* xvi+264 *pages; illustrations and charts.* 7*s* 6*d*

This is the author's second book. On this occasion he appears in the role of *raconteur*, but 'Adventuring in Coral Seas' is not up to the standard of his earlier production. After reading it one wonders what it is all about.

The book covers a wide sphere of interesting topics, but it leaves the impression of being a confused assemblage of personal experiences, reminiscences and anecdotes; of bright and interesting flashes into the realms of piscatology and ornithology; innumerable references to little-known places and less-known persons; incidents—commonplace, humorous, and extraordinary; in short, a medley of observations and experiences relating to the South Pacific, through which one can skim and be interested for an hour or so. In its composite form as a book, 'Adventuring in Coral Seas' is however unsatisfying.

The illustrations are interesting, but in many instances are not well reproduced. O. C. W. F.

THE PHANTOM PARADISE: The story of the expedition of the Marquis de Rays. By J. H. NIAU. *Sydney, Australia: Angus and Robertson* (*London: Australian Book Co.*), 1936. 8½×5½ *inches;* xviii+190 *pages; illustrations and sketch-maps.* 7*s* 6*d*

In writing 'The Phantom Paradise' Miss Niau has been at pains to piece together the tragic details of an adventure which, after nearly sixty years, has lost most, if not all, of its interest. The story is claimed to be the only "full and authentic record" of what is described as the "most incredible episode in the South Seas," namely, the expedition of the Marquis de Rays—a Breton aristocrat who is alleged to have played on the credulity of some hundreds of people,

principally French and Italian, and to have induced them to part with all their savings and emigrate to New Ireland, an island in what was then known as the Bismarck Archipelago, where it was intended to found a new French Colonial Empire. Abandoned to their fate on the fever-stricken shore of New Ireland, those pioneer colonists suffered incredible hardship; many were killed and eaten by cannibals; others died from fever, exposure, and starvation. A few of the more fortunate, and perhaps more hardy, ultimately found their way to Noumea, some to Singapore, and others to Manila. Those at Manila were subsequently taken to Australia. Among the latter was the author's father, to whose memory 'The Phantom Paradise' is dedicated. Miss Niau's sincerity of purpose in collecting and laboriously piecing together all the fragments of this ill-fated venture is commendable, but it is doubtful whether any useful purpose will be served in reviving the regrettable details of this almost forgotten swindle. The story is very involved and makes rather tedious reading.

O. C. W. F.

POLAR REGIONS

ARCTIC JOURNEYS: The story of the Oxford University Ellesmere Land Expedition, 1934–5. By EDWARD SHACKLETON. *London: Hodder and Stoughton*, 1937. 9×5½ *inches; 372 pages; illustrations and maps.* 21*s*

So many expeditions go to the Arctic nowadays and so many accounts of them are written that it is increasingly difficult to find a new method of approach. This Mr. Shackleton does not attempt to do, and his book is a very straightforward story of the expedition, which was the first organized by the Oxford Exploration Club to winter in the Arctic. It is always difficult to write of an expedition which, like this one, has split up into small parties for its spring work, but the author has given a clear account of this difficult period, and one is very apt to forget that this is his first book. This is no place to give a précis of the book, for a full account of the expedition has been given elsewhere in this *Journal*, but it may be profitable to see what lessons have been learnt.

In the first place, it is evident that Etah was not a good place at which to winter, because weather conditions were so bad, with almost continuous winds, that hunting was impossible in the winter, and a shortage of dog food resulted which delayed the start of the spring work. Eskimos were used extensively, and the lesson taught by Watkins, that they are by no means indispensable, must not be forgotten. Their disadvantages are apparent more than once in this book, particularly in Dr. Humphreys' account of his journey with Haig-Thomas, where they seem to have been a definite drag. Their influence is also discernible in other ways. The Eskimo uses his dogs mostly for short journeys to and from his hunting grounds, where he can feed them well; and he likes to travel fast, so he has a large team. But the economics of modern exploration in the arctic are rather different. Speed is seldom essential, but it is necessary to be able to stay out a long time, without having to depend on game, and for this small teams of about six to ten dogs per sledge seem best. Large teams eat more than they pull, and are uncontrollable as well, so that strong heavy sledges are essential. The author dismisses the light Nansen sledges as impracticable for pack-ice work, but one must not forget the long sea-ice journeys made with them by their inventor and by Sverdrup. They are immeasurably superior to Eskimo sledges when one is working on soft snow or thin ice.

Travel with these methods, though a large area was covered, made detailed exploration impossible, with the exception of the author's own journey with Bentham, on which a careful geological and topographical survey was made of the region round Scoresby Inlet. The reviewer however feels bound to

question the statement in the appendix that detailed survey is impossible in the spring. It has been done several times, by J. P. Koch, Isachsen and Nordenskiöld, to mention only a few. And, while on the subject of survey, the explanation of the long-continued full moon on p. 132 is erroneous. It is not true to say that "In the Antarctic this year the moon was not visible at the full." The Antarctic sees the full moon like the Arctic, during its own winter.

Apart from this slip the explanations, which are always so necessary in a description of arctic work, are good and are helped by one or two very good diagrams. In addition to these, drawings of arctic scenes by one of their Eskimo have been used as tailpieces. There are about forty good photographs, some of them very fine, an index, a map reprinted from this *Journal*, and ten appendices. The attraction of this book lies in the simplicity of its account, a simplicity which is often more effective than florid writing in a story of this kind. The book is also valuable for the descriptions it gives of some points of arctic technique.

J. W. W.

ARCTIC ADVENTURE: My life in the frozen north. By PETER FREUCHEN. *London: William Heinemann*, 1936. 10×7 *inches;* x+406 *pages; illustrations and sketch-map.* 21*s*

Possibly the most important quality of this book is that it holds the reader's interest. Others have written about the Eskimo, and in this book little information is available that has not been published previously. But it gives a full description of several Eskimo cultures contained in a series of stories of adventure, one tale following the other in a sequence of startling episodes. Peter Freuchen started his Arctic career in 1906 in North East Greenland as a member of the "Danmark" Expedition, as the colleague of such men as J. P. Koch and A. Wegener, under the leadership of Mylius-Erichsen. Soon after returning home to Denmark he met Knud Rasmussen, and from 1910 until the end of the Fifth Thule Expedition in 1924 he had the good fortune to be constantly associated with that genial explorer. The period begins with the starting of Rasmussen's trading station at Thule in North Greenland. These two young men, in spite of official discouragement, excluded everything else from their lives in order to direct this venture. They started with very little except their enthusiasm and Rasmussen's knowledge of the country and the people. They fought hard to make the post a success and it took them years to achieve it. It makes an excellent story; in the administration of the outpost journeys were made and accidents happened which prepare the reader for the larger scale events of the later expeditions.

The author himself was a member of the First Thule Expedition across North Greenland to Denmark Fjord; and of the great Fifth Thule Expedition to Arctic Canada. During the Second Thule Expedition Peter Freuchen remained in charge of the trading station, but gives us sufficient account of the scientist Wulff to enable us to see how misdirected any attempt must be to make either Rasmussen or Lauge Koch responsible for his death. The MacMillan Expedition was in the district during this period and the stories of its adventures make good reading. There are accounts too of Peary and of Greely, from the Eskimo who were with them: the former was in their eyes the greatest white man they had ever known. As the mosaic of tales develops we encounter such figures as Lauge Koch, Ejnar Mikkelsen, Therkel Mathiassen, Kaj Birket-Smith and many who as scientists or explorers have since become well known. But clearest and most alive of all these is the man to whom Peter Freuchen was for more than twenty years a faithful disciple, Knud Rasmussen; the enthusiastic Copenhagen student, the Dane with just enough native blood in

his veins to be acknowledged by the Eskimo as one of their own, the Arctic traveller whose feats of sledging will be long remembered.

There is much more in the book than its merely geographical content; in particular the figure of the author is dominant. It is conceivable that some readers may indeed be alienated by this large-looming figure who has written four hundred pages almost entirely in stories which approach the miraculous. Nevertheless there is a sincerity and unaffectedness, particularly in the description of his life with the Greenlander Navarana who became his wife, that can completely win the reader. His life with her and their children brought him much happiness. It is clear that a more detached writer would never have succeeded in conveying the beauty of the country, the life of the natives, and its inherent contentment; all without presenting the native as an embodiment of his own ideals.

If sometimes the accounts of familiar events read like stories often retold, we must remember that a too faithful rendering may conceal the essential inner truth: that the paint laid on boldly may convey more of the real atmosphere than the record of an over-attentive photographic lens. The book is in fact an excellent narrative of the Eskimo, and on completing it one may feel grateful to Knud Rasmussen and to Peter Freuchen for letting one learn about a community of people who have perfected a way of life. M. A. S.

NORTH OF NORTH CAPE: The Arctic voyages of the "Norkap II." By DUDLEY VAILL TALCOTT. *London: John Lane*, 1936. 9×5½ *inches;* xiv+316 *pages; illustrations and sketch-maps.* 15*s*

The names of some of the Norwegian sealers—*Quest*, *Heimland*, *Isbjörn*, *Hobby*, and others—are familiar to geographers on account of the part they have played in carrying expeditions to and from Spitsbergen and Greenland. The charter rates they charge for these voyages give nevertheless a misleading impression of the conditions under which they normally work. The sealers are vessels of about 100 feet in length and 200 tons burthen, built of wood, strengthened for ice, and engined with a Diesel. In such ports as Tromsö, Bodö, Aalesund these vessels and their skippers retain a local importance and character reminiscent of conditions which have vanished in Western Europe. Astonishing voyages are made by these craft, thousands of kroner are sometimes earned in a few weeks; the skippers are famous for their skill in ice-navigation and the crews for feats of strength and endurance.

This book contains information about the sealers and the economics of their almost romantic activity. We learn how in the winter they will have to earn money carrying cheap freights down the coast; and how in the summer the crew may have to be paid by selling unused fuel oil. Even the spring sealing voyage is by no means a sure venture, and the herring fishery is little less than a gamble. If a Tromsö skipper owns his ship and his nets he is accounted fabulously rich: many are in debt to the banks.

It is a pity that all the book is not as interesting as the account of the great occasion when *Norkap II* set a seine across Lille Torskefjord. The author is an American art student, who visited Norway, married a Norwegian, and went into partnership with his father-in-law in the running of this sealer, the *Norkap II*. He visited the East Greenland coast several times in the Franz Josef Fjord region, once for salmon and then with American tourists. (But even Isaksen failed to get his ship to Greenland in the ice-bound summer of 1935.) In spite of these tours his information about Greenland is very sketchy. J. P. Koch is described as the father of Lauge Koch: Angmagssalik is written Anjmassalik and Myggebugt Mygbuksta (p. 51). The Eskimos north of

Scoresby Sound are said to have become extinct because "the climate was too tough." And Gustav Holm's finding of Angmagssalik is described as the discovery of "a completely isolated village." The author has made no effort to understand the dispute between Norway and Denmark with reference to rights in East Greenland. "The whole Baltic Sea is always frozen solid for many months" is another instance of extreme carelessness, marring a book which, though it contains quantities of irrelevant matter such as discussions of marital ethics, nevertheless tells us something of a society which, in its struggle for an existence on the Arctic coasts of Norway, has retained qualities of initiative and tenacity which command our admiration. M. A. S.

PHYSICAL AND BIOLOGICAL GEOGRAPHY

PLANT AND ANIMAL GEOGRAPHY. By MARION I. NEWBIGIN. [Completed by FLORENCE M. NEWBIGIN, with the assistance of H. J. FLEURE and MARGARET DUNLOP.] *London: Methuen & Co.*, 1936. 9×5½ *inches;* xvi+298 *pages; illustrations and maps.* 12*s* 6*d*

The time was ripe for a geographer to survey the biologists' findings in the fields of ecology and taxonomic distribution, and for the task none was better qualified than the late Dr. Newbigin. Geography is thus under a deep obligation to her sister, to Professor Fleure, and to Miss Dunlop for bringing to us this last gift of her vivid personality.

Taking shape over a period of some years, the work arose from a series of lectures given at Bedford College. The stamp of its origin is still present; for the book is a collection of essays having the best features of lectures without usurping the place of reading. This is nowhere more apparent than in the short chapter of sixteen pages on plant response to environment. With hardly one specific reference to a plant, and without the quotation of a single climatic figure, one is left with a framework into which detail must fall naturally, and with an almost smarting sense of her keen strictures on the geographer's proneness to jump at unjustifiable correlations and at mechanistic views of vegetation and climatic control. In combination with the relevant chapters of Braun Blanquet's "Plant Sociology" and Lundgårdh's "Environment and Plant Development," this chapter paves the way for a view wide and complete, with trenchant illustration. It forms a section of Part I of the book 'Life and its Environment,' in which much is done to provide those having no preliminary discipline in biology with the minimum background necessary to an appreciation of biogeography.

Part II compresses and refines a subject, "Animal Habitat and Animal Adaption," which she had already made her own in her earlier "Animal Geography." Part III presents the outstanding results and problems of taxonomic distribution, while a final chapter (Part IV) outlines the approach to a study of Floral Regions in a discussion of the Holarctic and Mediterranean Regions and the British Isles.

Part I includes sections contributed by Miss Dunlop on Soil Classification and Climatic Change: difficult subjects which are clearly outlined in a mere forty pages. Exigencies of space seem the reasonable explanation of a tendency to give a rather deterministic view of soil factors in such expressions as "This condition of formation *makes* the brown earths the centre of mixed agriculture so characteristic of Western Europe, Eastern Canada and North Eastern U.S.A." Again, pressure of space alone could condone the assertion that "it is a well-known *fact* that the presence of the Quaternary Ice Sheet was responsible for the development of an anti-cyclone of enormous size and stability. Thus one

may assume . . ." The italics are the reviewer's and the mention of these blemishes would be quite ungracious were it not that this book is destined to influence large numbers of undergraduates. H. A. M.

DER ABBAU DER GEBIRGE. By ERNST KRAUS. Band 1: Der alpine Bauplan. *Berlin: Borntraeger*, 1936. 10½×7 *inches;* xii+352 *pages; maps and profiles. M.*30

The picturesque interpretation of Alpine structure developed by the Swiss geologists during the last forty years is familiar enough to English readers. The Swiss have no doubt that in the main it is correct, though they differ with regard to details; but most of the East Alpine geologists have never taken kindly to the gigantic recumbent folds that it requires, and they have always been more impressed by mechanical difficulties than their more imaginative colleagues. These difficulties led Ampferer in 1906 to formulate a new theory of mountain-building, and in essentials this is the theory adopted by Dr. Kraus. It supposes that in the magma beneath the Earth's crust there are currents, produced by convection or otherwise. Beneath the line of a future mountain range there is a descending current and the overlying crust sags downwards into it, forming a trough or geosyncline. Lateral currents flow in towards the descending magma, dragging together the edges of the trough and causing underthrusts towards its axis. This is a brief statement of the fundamental idea of the theory, but Ampferer carries his analysis much further. Near the end of the present volume the author gives a series of diagrammatic sections which illustrate very clearly his own idea of the subsequent developments. The reader will find it helpful to examine these sections with some care before he turns to the detailed studies of the Alps, which form the greater part of the volume.

In one respect Kraus's interpretation of the Alps differs entirely from any that have preceded it, whether West Alpine or East Alpine. According to him the Alps are not, in origin, a single range. There were two descending currents, one of which gave birth to the Northern Alps and the other to the Southern Alps. In expounding his view he gives a map, in colour, and a series of eight sections, also in colour; and in his text he examines each section in detail. The most westerly section is from the Isère to Turin, the most easterly passes through Graz. The reader will certainly be interested to compare these sections with those of the Swiss geologists. The differences are the natural consequences of the assumptions on which they are based.

The book should be read by all who are interested in the structure of the Alps or in the tectonics of mountains generally. The succeeding volume, or volumes, will presumably deal with other ranges. P. L.

ECONOMIC AND HISTORICAL GEOGRAPHY

SIR JOSEPH BANKS: His relations with Australia. By GEORGE MACKANESS. *Sydney, Australia: Angus and Robertson (London: Australian Book Co.)*, 1936. 8×5 *inches;* x+146 *pages; illustrations. 7s 6d*

Sir Joseph Banks is described by the author of this short but interesting book as having become by 1788 "general adviser to the English Government on all Australian matters," and its purpose is to justify this unofficial title. The material upon which it is based is the collection of Banks' letters, hitherto unpublished, which were secured for the Mitchell Library, Sydney, and the Commonwealth Library, Canberra, in 1928. Extracts from these, with the necessary supplement from published sources, have been woven together to

form a continuous narrative. It is not always easy however to distinguish the old from the new material. Among Banks' correspondents figure the well-known names of the early pioneers of Australian exploration and settlement, Captain Cook, Phillip, Hunter, King, Bligh, McArthur, and Flinders. There are some particularly interesting extracts from his correspondence with Bligh which help to explain the unfortunate course of the latter's governorship of New South Wales. In one matter which was paramount for the development of the colony, the introduction of sheep for the wool industry, Banks threw his influence on the wrong side; his opposition to McArthur, the initiator of the scheme, appears to have been based upon personal grounds, for McArthur was Bligh's bitterest opponent. No solution is yet forthcoming of a point which has frequently been noticed by writers, namely the apparent change in Banks' opinion as to the suitability of Eastern Australia for a settlement between the voyage of the *Endeavour* and the negotiations which culminated in the despatch of the first expedition to Botany Bay. Throughout the book there are many valuable sketches of men and scenes in early Australian history, which present contemporary life and its difficulties vividly to the reader. There are also a number of interesting portraits. G. R. C.

LE PÈRE DE LA LOUISIANE: Cavelier de la Salle. By CH. DE LA RONCIÈRE. *Tours: Mame*, 1936. 8×6 *inches;* 128 *pages; illustrations and maps*

The year 1937 will see the celebration of the two hundred and fiftieth anniversary of the death of the famous French explorer Robert Cavelier de la Salle. But there is as yet no definitive biography of la Salle, and the only comprehensive records of his expeditions were published in 1879, and edited by Pierre Margry, who has been called a "careless transcriber, and on occasion a perverter of the form and sense of what he printed as original manuscripts."

Joliet and Marquette were the discoverers of the Mississippi, but it was la Salle who opened up the valley of the great river. In 1681–2 he descended the Illinois and the Mississippi until he reached the three main channels of the immense delta, each of which was explored. This expedition was his greatest achievement; his later journeys were unfortunate, and on 19 March 1687 la Salle was murdered by some of his own companions. In Professor J. B. Brebner's words, "Hudson at one end of the continent, and la Salle at the other paid the same price for the same lack in qualities of leadership."

M. Charles de la Roncière's outline of the life of la Salle is a small volume that will serve a very useful purpose, especially in this centenary year. A larger work on this explorer is badly needed, as his life has been the subject of so much controversy. The book is illustrated with many interesting woodcuts and maps. E. W. G.

LUCIE DUFF GORDON, in England, South Africa and Egypt. By GORDON WATERFIELD. *London: John Murray*, 1937. 9×5¹/₂ *inches;* xii+358 *pages; illustrations.* 12*s* 6*d*

The first half of this most interesting and entertaining volume consists of memoirs of the author's great-great-aunt Lucie Duff Gordon and of her mother Sarah Austin. Both outstanding women in their day and generation, both scholarly translators of books, they were besides, each in her own way, brilliant, original, unconventional as well as strikingly beautiful. But though the first half may be the most attractive and original, it is with the second half that a review in this *Journal* must of necessity deal, for only that part describes Lady Duff Gordon's travels in Africa between the years 1861 and 1869, in which year, at the early age of forty-eight, she died of consumption on the Island of Philae above Aswan.

This second part is derived mainly from Lady Duff Gordon's books 'Letters from the Cape' and 'Letters from Egypt,' the latter published in 1865 and running into several editions at a time when the minds of people in Great Britain must have been atuned to tales of African adventure. But Lady Duff Gordon's books would certainly never have been written had she not been compelled to leave England to seek the health which she failed to find. Then, cut off from all associations of her youth and early married life, she threw herself heart and soul into the new life about her; and, with a marvellous faculty for entering into the minds of other, often of more primitive, people, left behind her valuable records of life in Africa. Thus, on her South African journey from Simon's Bay to Caledon, and during her residence there, she associated with the so-called "Hottentots" so despised by the Dutch and brought to them a rare sympathy and understanding.

During her years on the Nile, when for five and a half years she and her maid were the only Englishwomen living in Upper Egypt, Lady Duff Gordon completely entered into the life of the Arabs, talking to them in Arabic, sitting down with the fellaheen and treating "every one as they treat each other." She entered into their innermost thoughts, which she set on record for future generations. " I am in love with Arab ways," she writes, and she showed it by adopting the fellaheen dress when her stock of European garments gave out. Although she may have dressed like the fellaheen, she formed close friendships with the high-bred Arab. "The feelings and prejudices and ideas," she wrote, "of a cultivated Arab as I get at them little by little are curious beyond compare."

But in spite of the love she found among the people of the Nile her heart yearned for her own people. Yet, when she knew that her end was near she would not let them come from England to see her die. She was cared for by the "good, loving crew" of her *dahabiah*, and by one white woman, unable for the last twelve days of her life to lie down for the cough that choked her. She herself wrote out the telegram to announce her death to her husband, leaving only the date blank. Surely Lady Duff Gordon was, as Meredith said, one of an order of women "met with but once or twice in a lifetime." E. W. N.

GENERAL

HIGH FAILURE: Solo along the Arctic air route. By J. GRIERSON. *London: William Hodge & Co.*, 1936. $8\frac{1}{2} \times 5\frac{1}{2}$ *inches;* xii + 306 *pages; illustrations and route-map.* 12*s* 6*d*

The sub-title gives the reader at once, in a nutshell, exactly what this admirably illustrated book is about. On 4 August 1933 Mr. Grierson took off from the Humber in an 85-h.p. Gipsy Moth in an attempt to reach New York *via* the North Atlantic route. Unfortunately for him this attempt was filled with disaster, and after crashing at Reykjavik in Iceland he had to abandon his attempt and return with the wreck of his aeroplane. Nothing daunted, he still decided that a solo flight over this route was possible, and on 20 July 1934 he took off from the Medway in a Fox Moth, which was destined, after many adventures, to reach its objective.

Whether Mr. Grierson is correct in his assumption that the North Atlantic route is the better way for trans-Atlantic aerial transport is open to debate, but he proved that single-handed, without capital of any reasonable proportion, ill-equipped with regard to machine, and with the barest possible preparations for bases, it could be done with tremendous difficulty and considerable danger. His book is a story of courage in distinct adversity and the will to carry out what he himself firmly believed to be pioneering of international importance.

To all interested in exploration, not merely from the aviation side, but from interest in the unknown, his story is one that will command attention. He tells us graphically of how he took French leave of the Royal Air Force in India and unconsciously broke the record for a return flight from India to England when doing so. He gives us a very clear-cut story of winter flying in Europe, during which he tested sundry apparatus and obtained as large a knowledge as possible of the wintry conditions which he might expect in the Northern regions. His actual flights are enthralling, and he is as outspoken in his failure as in his honesty of purpose.

It is impossible to say whether the short-stage North Atlantic route will prove eventually preferable to the long sea crossing at present contemplated or not, but Mr. Grierson has shown us that if such a route could be traversed by one so handicapped there must indeed be something in it if properly organized schemes were inaugurated. Apart from its value as a study of Northern air routes, his book is one long adventure of a most graphic and readable type.

D. F. M.

THE STORY OF SAIL. By G. S. LAIRD CLOWES. *London: Eyre and Spottiswoode*, 1936. $10\frac{1}{2} \times 8$ *inches;* 148 *pages; illustrations* (by CECIL G. TREW). *10s 6d*

To encompass the story of sail in a volume of only 147 pages, of which 53 are devoted entirely to illustrations, requires not only a wide knowledge of the subject, but a nice sense also as to what must be selected from the mass of material available. Mr. Laird Clowes has successfully presented a clear-cut story logically told stage by stage.

The book is divided into two main sections, of which the first is devoted to the general development of sail, starting indeed with primitive craft of types which preceded its introduction, and concluding with the big steel barques of the post-clipper-ship era. The second section, which is much shorter, is concerned entirely with yachts, from the Stuart Royal Yacht of 1672 to *Enterprise* of 1930. The author prefaces each section with an introductory essay. Of these the first, and necessarily the longer, which introduces the forty-seven plates of sailing ships, each with a descriptive account, is a model of comprehension and compression. In twenty pages the author has succeeded in tracing on broad lines the introduction and development of the more important types of ship and the chief varieties of sail. A shorter essay tells of yachts and their development. The rest of the book is devoted to fifty-three whole-page plates, each with one drawing of a particular type of ship, faced by a page of descriptive and historical information. Where an ancient type has survived almost unchanged until the present day, the author has inserted pictures of each period in immediately succeeding plates, enabling interesting comparisons to be made. A boat at Ur, in Mesopotamia, of about 3500 B.C., for example, is compared with a modern canoe in Southern Iraq; and again, in the reed fishing boats of ancient Egypt and the modern *balsas* on Lake Titicaca ancient and modern primitive craft of similar types are carefully contrasted.

The pictorial method of representation enables the whole story to be quickly grasped. The obvious influence of E. W. Cooke can be traced throughout. It must be admitted however that Mr. Trew has not the advantage which Mr. Cooke had in understanding exactly the practical significance of all that he drew. The drawing of a Humber keel for example is a delightful piece of work, but that of the yacht *Enterprise* gives only the crudest representation of the original. In the picture of the Arab dhow, the position in which the yards are shown slung *inside* the shrouds, is in direct contradiction to the account in

the text, where the author is careful to explain that these craft wear round *away* from the wind instead of tacking *into* the wind when they have to go about, shifting the yard and sail over and round the *fore* side of the mast, outside everything, which would be impossible if the yards were slung within the shrouds as shown in the drawing. These small points would scarcely be worth mentioning were not the book generally so much above the average. It is a book to be enjoyed at first reading, studied in detail at leisure, and then kept handy for reference by all who are interested in sail. F. G. G. C.

THE CLEAR MIRROR: A pattern of life in Goa and in Indian Tibet. By G. EVELYN HUTCHINSON. *Cambridge: University Press*, 1936. 9×5½ *inches*; xii+172 *pages; illustrations and sketch-map*. 8*s* 6*d*

Mr. Hutchinson has avoided banality, which is the worst pitfall of impressionism and inconsequence. But his style, to be successful, must be vivid enough to awaken like trains of thought in the mind of the reader; must be "mind-disturbing," as indeed the publishers claim. Chapter I fulfils expectations. For some odd reason it is entitled "Spain at Sea," when it deals mainly with Portugal; but most people will appreciate the vision of Goa, and its art, its temples and its churches, and the plates with which they are illustrated. Thereafter the quality is uneven; the link, "the pattern of life," is slender. Mr. Hutchinson was a biologist on the Yale North India Expedition. Those who appreciate the description of Tibetan art and dances, or who are intrigued by the Christian inscription at Tangtse, may very likely find the geology and ichthyology tedious. In its latter stages, in fact, this is not as "unusual" a travel book as it sets out to be. J. P. H. M.

ESCALES AUTOUR DU MONDE. By FABIENNE DE CROIZET. *Paris: Société d'Editions géographiques . . .*, 1936. 9×6½ *inches*; 250 *pages; illustrations and route-map*. 20 *fr.*

This is an account of Mme. de Croizet's third tour of the world, and on this occasion she visited South Africa, Java, Bali, Sumatra, Siam, Penang, Central America, and Cuba. The journey, which is written up in the form of a journal, extended over more than two years; and although Madame de Croizet did not stray far from the beaten track as a rule, a spirit of adventure displayed on several occasions suggests that timidity was not responsible. The authoress has descriptive ability, and her book is written in a bright and vivacious style. Perhaps the most interesting chapter is that which deals with the visit to Bali, where the ancient custom of *suttee* was carried out until comparatively recent times. The last instance occurred in 1903, and appears to have led to the despatch of a military expedition against the local Rajah, whose reception of the Dutch troops is most entertainingly described. Equally interesting is Mme. de Croizet's account of the cremation ceremony on a gigantic scale, preparations for which had been made for a year in advance, including the preservation of a number of corpses for the occasion. The authoress is a little severe upon the English in places. The suggestion (p. 103) that we had left Siam to the Siamese merely because the country was so unproductive might have been omitted.

The half-page illustrations are good, but some are not entered opposite the passages to which they relate. It may be remarked that von Spee did not command the *Emden*. W. G. G.

THE MONTHLY RECORD

THE BIANCO CHART, 1448, AND THE "PILLARS OF HERCULES"

We have received an interesting note from Mr. Charles E. Nowell, of Fresno, California, of which the following is a summary:

The second portolan by the Venetian cartographer, Andrea Bianco, constructed in London in 1448 has caused some controversy because of the appearance thereon of the "ixola otinticha" believed by Yule Oldham and others to represent Brazil. The chart also raises the question of the possible discovery of the Cape Verde Islands a decade before the historically recorded discovery by Cà da Mosto or de Noli in 1456. To the west of Cape Verde, two islands are shown, elongated from north to south, separated by a narrow channel, and labelled "dos ermanes." Their highly conventionalized shapes have led scholars to believe that if these islands represent any part of the Cape Verde Islands, they can have been sighted only, and not explored, prior to their appearance on Bianco's chart. Fischer, Yule Oldham, and Errera have in fact accepted these islands as recording a partial discovery of the archipelago by an unknown mariner.

It now seems however that these islands have no connection with an actual discovery, but were copied from an earlier map, and rest upon a classical tradition. On the chart of Mecia de Viladestes of 1413, made two years before the capture of Ceuta and the beginning of Portuguese exploration of West Africa, two islands appear in the lower left-hand corner, which correspond to the "dos ermanes" in shape and position, though the African coast is not continued beyond Cape Bojador. Despite minor differences of contour the two pairs of islands are essentially alike. On the Mecia chart there are two inscriptions; to the right of the eastern island it is possible to read the word "gades"; a conjectural translation of the inscription below the islands is "The islands of gades are placed here by Pliny the Younger and Isidore." This version is presented with reservations, as the writer has been able to consult the reproduction in C. de la Roncière's 'Découverte de l'Afrique' only. It is thus apparent that the islands were copied by Bianco from the chart of Mecia de Viladestes or from another of a common origin; they can therefore have no authentic bearing upon the discovery of the Cape Verde Islands. Having no further information to guide him, Bianco adopted the expedient of labelling the islands "dos ermanes" because of their twin appearance.

There can be no doubt that Mr. Nowell is correct in concluding that the "dos ermanes" of Andrea Bianco are based ultimately upon a classical tradition, which was current throughout the Middle Ages. Professor E. G. R. Taylor has already pointed out (*Geogr. J.* 67 (1926) 282) that the two islands appear on the Este map of *circa* 1450. The inscription accompanying them is read by Kretschmer as "Illa de cades asi posa ercules dues colones." This legend of the columns of Hercules, said to have been erected on each side of the Strait of Gibraltar to mark the limit of the known world, is referred to by Isidore of Seville and by Pierre d'Aily in his compilation 'Imago Mundi' written in the third quarter of the fourteenth century. The growth of the tradition is described in detail by Kretschmer in his 'Entdeckung Amerika's,' chapter three. The first stage in the migration of the columns was their transference to the island of Gades—which explains the "gades" and "cades" of the fifteenth-century cartographers.

Other cartographers somewhat later than Bianco continued to insert references to these columns, though their exact site, as the known world expanded, caused them some difficulty. The great world map of Fra Mauro, 1459, has two inscriptions referring to these columns. In the Atlantic to the west of Gibraltar there is the warning that they are simply the mountains on each side of the Strait. On the southern side of the large West African gulf there is a longer inscription to the effect that the cartographer had often been told that a column stood there to mark the limits of navigability, but that he would not vouch for this, as the Portuguese sailors should be consulted about it. In this instance the Hercules legend appears to have been combined with the supposed impossibility of navigation beyond Cape Non. A somewhat similar version appears on Behaim's globe of 1492: "when Hercules had reached here with his ships and saw the declivity of the sea he turned back and set up a column, the inscription upon which proves that Hercules got no further . . ." It is clear that, as knowledge extended, the site of the columns was pushed farther from the Straits of Gibraltar, and that the inscription of the Fra Mauro map is a sign of growing scepticism about their existence. There can be no question therefore of basing an early sighting of the Cape Verde Islands upon the "dos ermanes " of the Bianco chart. G. R. C.

JEWISH SETTLEMENT IN ECUADOR

Mr. Golodetz and Mr. Henriques, joint authors of the "Report on the possibilities of Jewish settlement in Ecuador" (London: B. Weinberg, 1936. Price 5*s*), visited Ecuador in spring and summer 1936 in order to examine the possibilities of Jewish settlement there. They went on their own initiative and at their own expense, being convinced (as it is clear that others of their community are not) that Palestine cannot accommodate the many thousands of Jews who are compelled to emigrate from Central and Eastern Europe. Mr. Golodetz is an economist and Mr. Henriques an irrigation engineer; and it may be presumed that the optimism displayed in their report is well founded, although they spent only some ten weeks in the country. Accurate statistics are difficult to obtain, but the population density is estimated at 14 per square mile. The authors of the report reckon that there are 10,000 square miles of cultivable land immediately available on the western slopes of the Andes, at an altitude of from 4000 to 10,500 feet, which (if the population density equalled that of Palestine) would accommodate 1,400,000 people. The necessity of maintaining a proper balance between agriculture and industry is emphasized. In Ecuador, where only 16·5 per cent. of the population lives in the towns (mostly in Guayaquil and Quito), there is obviously no scope for the immigrant professional, and little (at first) for the manufacturer. Ecuador is reasonably well endowed with natural resources, and her industries are undeveloped; but in the present state of world economy it is doubtful how far her exports could be expanded. The authors suggest that small traders and craftsmen, of the type that Eastern European Jews could well provide, would be the most acceptable immigrants outside the field of agriculture.

One half of the report consists of appendices enlarging the main headings of the authors' findings. Estimates of the cost of settlement, and of the possibility of organizing industries based on local agricultural produce, together with a brief description of the authors' journeys about the country, are included. There is a map of Ecuador which does not, unfortunately, show altitudes. A plan and full details of a concession already negotiated by a Jewish community in Paris are provided.

THE ERCIYAS DAĞI REGION OF ANATOLIA

Dr. G. Bartsch contributes a systematic and detailed study of the Erciyas Dağı and the surrounding region to the *Jahrbuch* of the Hanover Geographical Society for 1934–5, the result of field studies in 1930 and 1932. The Erciyas Dağı (3916 metres), the highest summit in Asia Minor, dominates the south central Anatolian plateau, and the author's purpose is to show its close relationship, in physical and human geography, to the surrounding region. The massif, of volcanic origin, rises on the east directly from the high steppe; but in other directions it is cut off by the Kayseri basin and the salt swamp of Sultan Sazi. Three morphological zones can be distinguished: a broad pediment of crystalline schists, overlain by volcanic deposits covered by andesite lava flows, rising in stages up to 1700 metres, and on the western slopes to 2000 metres. Above this, the central mountain region is strongly differentiated by its rounded summits and tangle of small plateaux, clefts, valleys, and boulder fields. The summit zone is steep, broken by large cwms, ridges, and moraines, formed when the snow-level was much lower. There is still a small glacier on the north-west. The volcanic activity is dated between late Tertiary and Quaternary times, when the whole Anatolian block was elevated. The accompanying lowering of the erosion basis contributed to the denudation of the massif. The rainfall being comparatively light, much of the breaking down of the rock has been mechanical.

The author demonstrates the close connection between the massif and the surrounding volcanic plateau, extending on the south as far as the Taurus range, and relates the zones of human occupation to the morphology. The pediment is characterized by villages among gardens and cultivated fields; the central mountain zone by pasture and scrub, with temporary settlements. The neighbouring basins are ringed by comparatively dense agricultural settlements. The monotonous high plateau, broken occasionally by mountains, is given up to agriculture and cattle raising. The seasonal movement to the summer settlements, principally on the west of the massif, is analysed in detail, and there is also a study of the distribution of population and of the development of Kayseri, which had approximately 40,000 inhabitants in 1927. The monograph is accompanied by a photogrammetric survey of the massif on the scale 1/80,000 by Dr. Penther, and several good photographs.

POINT PIGOTT, MOUNT KENYA

Mrs. Louisa Pigott has drawn our attention to the spelling of "Point Piggott" on maps of Kenya. This point on Mount Kenya was named by Professor J. W. Gregory after her late husband, Mr. J. R. W. Pigott of the Imperial British East African Company (see *Geogr. J.* 4 (1894) 415). Through an error on the part of Professor Gregory the name has come to be spelt wrongly on maps, the correct form being "Point Pigott."

THE SAIDMARREH LANDSLIP, SOUTH-WEST IRAN: CORRECTION

In the paper by J. V. Harrison and N. L. Falcon (*Geogr. J.* January 1937), the depth of the lake (p. 47, line 26) should be 1155 feet.

Tenth Evening Meeting, 22 March 1937. Admiral Sir William Goodenough, Vice-President, in the Chair

Elections: L. N. Agarwala, M.A.; Alfred Copp Bond; William George Bruce; W. T. Morton Davies, M.B.E.; Reginald Burton Dennis; Joseph Crookes Grime, O.B.E., F.C.I.S., J.P.; Hugh Arthur Cotes James; Frederick Alfred Keen; Robert Ridge Mander; H. G. Moore; Taw Soe Tin, B.A.; Frederick Charles Thompson (1/24 South Wales Borderers)

Paper: Explorations in Northern New Guinea. By Mr. A. J. Marshall

Eleventh Evening Meeting, 5 April 1937. Colonel Sir Charles Close, Vice-President, in the Chair

Elections: Mohammed Ameen Akbar; Thomas Auckland; H. P. R. Chowdhury, M.A.; Madame Eleanor Rigo de' Righi; Edwin L. Monk; William Edward Olpin, B.A. (Com.); E. Simpson

Paper: A Journey in the Tsangpo and Salween Basins, S.E. Tibet. By Mr. Ronald Kaulback

Twelfth Evening Meeting, 19 April 1937. The President in the Chair

Elections: Brigadier Walter Tyrrell Brooks, M.C.; Squire Clegg; The Rt. Hon. the Lord Fairfax of Cameron; John Miller Pattinson; Miss May Peacock; Charles Robertson Porter, M.R.C.S.; Miss Phyllis Irene Wallis; Owen Lee-Williams, M.A.; The Rev. E. Maynard Wilson

Paper: The Dadessa Valley. By Captain A. Dunlop

Seventh Afternoon Meeting, 12 April 1937. Colonel Sir Charles Close, Vice-President, in the Chair

Paper: The Geographical Ideas of Robert Hooke. By Professor E. G. R. Taylor